1993

Measuring the benefits of water resource protection from agricultural contamination: results from a contingent valuation study

Premachandra Mathuwansa Wattage
Iowa State University

Order Number 9321223

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Wattage, Premachandra Mathuwansa, Ph.D.

Iowa State University, 1992

U·M·I
300 N. Zeeb Rd.
Ann Arbor, MI 48106

Measuring the benefits of water resource protection

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by

Premachandra Mathuwansa Wattage

A Dissertation Submitted to the

Graduate Faculty in Partial Fulfillment of the

Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Department: Forestry
Major: Forestry (Forest Economics)

Approved:

Signature was redacted for privacy.

In Charge of Major Work

Signature was redacted for privacy.

For the Major Department

Signature was redacted for privacy.

For the Graduate College

Iowa State University
Ames, Iowa

1993

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CHAPTER 1 INTRODUCTION

Agriculture and Water Quality

World natural resources such as land, water, air, wildlife, and vegetation are facing a threat of either misuse or overuse as a result of various human activities. To meet the demand of growing population for food, the agricultural industry has relied on heavy mechanization, hybrid varieties, chemical fertilizers, and pesticides. U.S. pesticide, herbicide, and fungicide sales grew an average of 6 percent per year between 1965 and 1974, fluctuated throughout the 1970s then fell along with farm financial conditions and acreage cutbacks in the 1980s (Runge 1990). According to the International Fertilizer Development Center (Baanante et al. 1989), agricultural production increased from 1961-1963 to 1983-1985 at an annual rate of 2 percent in developed countries and 3.2 percent in developing countries. About two-thirds of these increases were due to increases in yields, as distinguished from increases in area planted (Baanante et al. 1989). Fertilizer use, which increased tenfold in developing countries and doubled in developed market economies from 1961-1963 to 1983-1985, is possibly the most potent single factor in raising productivity (Food and Agriculture Organization 1987). National and local governments in every part of the world have encouraged the development of agricultural production capacities while, in the view of some, simply neglecting perceived health risks or socio-economic and environmental impact.

Agriculture impacts heavily upon water use and thus ultimately upon water quality. Agriculture is part of the water pollution problem in the United States and in other parts of the world (Batie 1988). Expansion of chemical use in the United States was accelerated in the 1960s and 1970s. Between 1964 and 1985, the use of pesticides by farmers more than tripled and the use of nitrogen fertilizer increased to 10 million metric tons per year (Batie 1988). Increasingly, agricultural chemicals are indicted as possible human health risks, as catalysts in the evolution of pesticide-resistant plants and insects, as destroyers of non-targeted species, and as creators of new pest infestations (Batie 1988). Farmers and governments always have been concerned about improving production methods to increase yields, receiving better prices and expanding and protecting markets. Until the 1980s, few farmers and governments were concerned with environmental matters associated with farming.

Production-oriented activities, such as the use of new agricultural technologies, crop practices, hybrid varieties, chemical fertilizers and pesticides, are associated with unintended and undesirable environmental consequences. For example, hydraulic alteration of waterways, extensive loss of natural ecosystem, and disruption of wildlife habitats and populations have occurred on millions of hectares of available lands worldwide.

There are three ways to describe the water-agricultural-environmental impacts that occur with modern farming techniques, especially those in the United States. First, the agricultural production process generates residuals from the erosion that can contaminate both ground and surface water sources. Nutrients, primarily nitrogen, phosphorus, and potassium, are widely used as fertilizers in agricultural crops to promote growth. In addition, livestock wastes are a source of nitrogen and phosphorus. Nutrient levels in excess of crop uptake are potential sources of pollution of both ground and surface waters. Thus, water quality and quantity is a serious environmental problem in many areas of the world as impacted by agricultural production (Batie 1988).

Second, the composition and timing of agricultural waste flows create enormous environmental problems (Lawrence et al. 1990). This could be modified by changing crop mixes, by changing production practices such as input substitution and timing of application of fertilizers, and by the introduction of new technology that alters the output-waste ratio.

Third, the production process affects the spatial and temporal dimensions of water outflows, which in turn affect the delivery and transport of the potential pollutant loadings (Batie 1988). This introduces important interactions and trade-offs between potential loadings and ultimate delivery to ground or surface waters.

The sources of residuals from agricultural activities are soil sediments, nutrients, pesticides, mineral salts, and disease organisms. Soil erosion is a natural result of cultivation practices and is the biggest source of pollution in the world. Factors influencing erosion are rainfall intensity and duration, soil erodability, field topography, vegetative cover, and tillage practices. Production systems that include contouring, reduced tillage, and crop rotation help control soil erosion. The concept of Vegetative Buffer Strips (VBS) along waterways as a means of reducing soil erosion and chemical runoff from agricultural fields is relatively new to North America.

To promote the growth of agricultural crops, many nutrients such as nitrogen, phosphorus and potassium are applied as chemical fertilizers. In addition, livestock wastes use as a common source of nitrogen and phosphorus. The nutrients levels in excess of crop uptake are potential sources of pollution of both ground and surface waters. This can be reduced by modifying the amount, timing, form, and placement of fertilizers. Research suggests that VBS along waterways are effective in absorbing nutrients moving through the vadoze zone, which otherwise would end up in ground and surface waters (Alberts et al. 1981).

Controlling undesirable vegetation, such as weeds, and pests typically requires the use of chemical compounds. These compounds generally are known as pesticides, and include herbicides, insecticides, nematicides and fungicides; these are applied to control weeds, insects, nematodes and diseases, respectively. Excess amounts of these chemicals are potential pollutants of both ground and surface waters. As with chemical fertilizers, externalities are minimized by proper amount, timing, form, and placement of the application.

Two decades ago, the advent of chemical herbicides seemed to reduce the importance of tillage as the primary method for eradication of weed species. However, applications of herbicides and fertilizers are currently practiced with various soil management methods that tend to increase the rates of infiltration. The ultimate result is a reduction of crop failures but an increase of water soluble chemicals and pesticides leaching into surface and ground water through infiltration. The movement of compounds with eroded soil into surface water can be successfully controlled by VBS.

Controlling leachate that enter ground water via infiltration is difficult or impossible with the use of VBS.

All surface and ground water supplies contain some minerals derived from natural dissolution of various rocks and soils. Irrigation water applied to crops carry these minerals into the vadoze zone and the minerals are either left behind as the water evaporates or taken up by plants. However, this is not a problem in Iowa area. Crop growth is inhibited by excessive mineral content in the soil and in solution. The only way to solve this problem is to let excess water leach the minerals beyond the vadoze zone. However, the minerals then would end up in the irrigation return flow or in the ground and surface water sources. Salinization is a major problem in many arid regions where large quantities of saline irrigation water are applied and very little rainfall is available to dilute and leach the accumulating salts.

Heavy metal constituents such as lead, zinc, mercury, and arsenic as well as certain disease organisms such as coliform bacteria and viruses are associated with the livestock production processes via manures produced. These heavy metals and disease organisms are sources of ground and surface water pollution, and may be controlled by appropriate handling and treatment of livestock manure.

Pollutants generally are classified by point source (PS) or non-point source (NPS) origin. PS pollutants are those that can be traced to a precise source defined as a "discernable, confined, and discrete conveyance," such as pipe, ditch, well or container [33 U.S.C#1362(14)(1982]. In agriculture there is relatively little PS pollution, and the majority of pollution is classified as NPS pollution. The origins of these pollutants are runoff and leaching from manure disposal areas and from the land used for crop and livestock production. Because it is difficult to trace such pollutants to a precise source, the management of NPS pollution is difficult and expensive. Furthermore, spatial and temporal variability complicate the measurement of liability for ultimate damage. Pollutants of this nature move in water as suspended solids or in solution. In general, the pollutants transported as suspended solids include soil sediment and heavy metals. Those chemical compounds, mainly pesticides and some fertilizers, which are absorbed into the soils, may be carried along with suspended sediments in the runoff. Pollutants dissolved in water and transported in solution include nutrients such as nitrate, some pesticides, mineral salts, and dissolved organisms. Thus, pollutants in solution are the dominant agricultural source of ground water contaminant and the sediment and absorbed compounds are important additional source of surface water contaminants. The interaction between ground water and surface water takes place because of recharge and discharge phenomena, causing the mixing of existing pollutants.

Pollutants that are transported as sediments or absorbed into sediments can be controlled by reducing the erosion and establishing a VBS, whereas pollutants that are transported in solution can be effectively controlled by reducing the availability and solubility of the compounds. The VBS also is effective in absorbing excess soluble compounds in vadoze zones (Young et al. 1980).

The impact of agricultural pollution in surface water bodies is of concern for two reasons. First, agricultural NPS pollution affects agricultural productivity. Soil productivity is reduced as a result of erosion and loss of nutrients. Likewise, losses of pesticides reduce the effectiveness in combating pests, resulting in lower productivity and increased cost. The estimated economic loss due to soil erosion alone in the United States has been estimated to be one billion dollars per year (Ribaudo 1986). The other reason for concern is the agricultural pollution that arises from the externalities associated with agricultural production. The damage is passed on to the general public as users of ground and surface water. Health risks from contaminated water have been reported in the United States as well as many other parts of the world. Further, soil particles that are suspended in water cause damage to aquatic organisms, water storage capacities, navigation, and water-based recreation. Aquatic organisms, fish, and other aquatic life are affected by sediments through the elimination of spawning areas and food sources.

Siltation reduces water storage capacity, which ultimately can cause flood damage and subsequent problems. Further, water-based recreation activities, including fishing, boating, and swimming are adversely affected by sediments in terms of increased maintenance costs of dredging ditches and irrigation canals or by the necessary construction of additional waterways.

The cost of treating water for municipal and industrial uses increases as pollution rises because sedimentation basins must be built, chemical coagulants added, and filters cleaned more frequently. The water quality impacts from pesticides and nutrients are complex because of the indirect interaction between chemical and biological compounds. The excess of nutrients in water bodies stimulates rapid growth of aquatic micro and macrothytes, which in turn affects aquatic habitats. Changes in plant species and distribution affect food supply and cover, which will influence growth of fish. On the other hand the growth of surface mycrophytes interferes with aquatic sports. The decomposition of algae and other vegetation can combine with other biological oxygen-demand loadings to deplete oxygen levels in the water, a harmful situation for many living organisms.

The off-stream impact of excess nutrients on drinking water is the major problem. The nutrients in a toxic form or combinations of the toxic compound could influence the growth of algae, which hampers water purification. In general, toxic levels of nutrients are rare, but for example an excess level of nitrate can cause methemoglobinemia in infants. The potential damage due to toxic chemicals and disease organisms largely depends on its level of toxicity, solubility and persistence.

Pesticide contamination may cause acute results in humans, and adversely affect the fish population. The most common, chronic effects are impaired respiration, reproduction, or locomotion. The pesticide concentration in animal tissue, becomes increasingly concentrated as it is passed up the food chain. Furthermore, pesticides destroy natural habitat, which could indirectly affect aquatic species by reducing food availability. The off-stream use of water for drinking purposes, irrigation, and use of industrial activities also are affected by the toxic compounds. High concentration of toxic compounds in drinking water can have chronic effects in humans including cancer, miscarriage, and mutations. On the other hand the removal of pesticides from drinking water is rather difficult and expensive. Mineral salts in drinking water cause problems related to health, taste and corrosion. The use of such water in industry is limited because of the corrosion the salts cause as well as its effect on certain chemicals. High concentrations of pesticides in irrigation water would damage the crop growth and the yield.

PS pollution from agriculture is not common, but sources such as abandoned wells and pesticide spills can cause potential damage to ground water sources.

Iowa Agriculture and NPS Pollution

Iowa, as well as many other Midwestern agricultural states faces a serious threat from NPS pollution in the water resources. The dispersed NPS pollution mixes with soil particles from uplands and deposits them in bottom lands where the pollutants can enter the aquatic environments of streams, ponds, and lakes. Sediment from the erosion of agricultural lands is the most significant volume of NPS pollution in many parts of the state, and many regard it as the most deleterious cause of numerous direct and long-term ecological and economic impacts. Nearly 240 million tons of Iowa topsoil slowly but persistently slip in the direction of the Missouri River and points beyond each year (Kelley 1990). Saylorville Reservoir on the Des Moines River, for example, averages 4,500 tons of incoming sediment a day, while the Red Rock Reservoir further downstream is receiving an average of 16,500 tons each day (Kelley 1990).

During the 1991 growing season, many surface water drinking sources in Iowa have reported nitrate levels beyond the acceptable level. Studies of water from tile lines draining from farm lands upstream from Des Moines, Iowa have shown nitrate concentration of 70 to 80 ppm. The level recommended by the United States Environmental Protection Agency (USEPA) for drinking water is no more than 10 ppm. Pesticides such as atrazine, and alachlor have been found in Midwestern surface waters for some time. A recent United States Geological Survey (USGS) study of streams in 10 Midwestern states reported that atrazine and alachlor concentrations in Old Man's Creek near Iowa City, Iowa were 71.6 ppb and 51.3 ppb, respectively. Concentration for the same two pesticides in the South Skunk River near Oskaloosa, Iowa were 42.1 ppb and 41.3 ppb, respectively (Kelley 1990). Recently, several herbicides have been detected in shallow aquifers that provide drinking water to many rural Iowa residents. In the next few years, the Des Moines water works, which has just invested $4 million in capital for equipment to filter nitrates from its water sources-the Racoon and Des Moines rivers-may have to invest an additional $13.5 million for a filtration system consisting of granular activated carbon plant to remove the herbicide atrazine (Hubert, 1992).

NPS pollution is by nature diffuse and often poorly defined, and beneficiaries of abatement are many and broadly distributed. It seems unreasonable to expect an agricultural jurisdiction to enact water pollution abatement measures associated with farming sufficient to produce water quality net benefits for downstream users in other jurisdictions (Lawrence et al. 1990). Therefore, the solution to NPS agricultural pollution should be initiated by polluters such as farmers and land owners. Furthermore, the existing legal and administrative regulations were not aimed at controlling these NPS pollutions. The congressional determination to improve water quality through the Water Pollution Control Act of 1948 and its subsequent amendments proved effective in ameliorating PS pollution control through various specifications and licensing for discharging effluent and through investing in municipal sewage treatment plants. However, NPS pollution has been more difficult to control through specifications and efficient discharge standards.

Although there was public attention in the 1960s on widespread chemical use in the United States, attention to water problems from NPS pollution did not occur until the late 1970s. NPS agricultural pollution was given special attention by the Soil and Water Conservation Act of 1977, the Food Security Act of 1985, and the Food, Agriculture, Conservation and Trade Act of 1990. Several bills also have been passed by the Iowa assembly although they were not effective in controlling NPS pollution.

The damage to water resources caused by NPS-related activities depends on the pollutant transport and fate in the sub-surface environment. Thus, a complex process requires an interdisciplinary analysis and interpretation because the processes involved in these activities are naturally intertwined. Examining each process in isolation would be of no use. Therefore, each transport process must be viewed from the broadest of interdisciplinary viewpoints and the interactions between them identified and understood. To have a sound conceptual basis, integrating information on geologic, hydrologic, chemical, and biological processes into an effective contaminant transport evaluation requires data that are accurate, precise, and appropriate to the intended problem scale. Finally, a sound methodological approach is required to measure the extent of the agricultural NPS pollution, its impact and the measures available to ameliorate damage.

Environmental problems associated with agricultural activities are special in a number of ways. They are widespread and not confined to a few, easily identified polluters. Moreover, the polluters are interdependent, since some of the pollutants running off one farmer's field may actually originate on other fields further up-slope. It is almost impossible, therefore, to keep track of the polluters or to separate their responsibilities and accountabilities. Thus the public policy with respect to the NPS pollution from agriculture is difficult to implement. Further, few pollution control technologies exist that can be readily identified, purchased and installed on farms. There are no simple add-on devices for intercepting and neutralizing most agricultural pollutants. Abatement generally requires systematic changes in farming practices, including chemical inputs, tillage practices, crop mixes, and farm-field configurations. These changes can be supplemented with changes in stream bank stabilization or VBS along the riparian zones.

The challenge in resource economics is to clarify the consequences of the physical and biological reality that farming affects water quality. Thus, the methodology should be developed to measure economic losses attributed to polluted water, the cost of alternative abatement strategies, and the expected returns.

Objectives of the Study

The focus of the study is on the measurement of benefits of environmental improvements through VBS and other management practices, which would control agricultural runoff from farm lands. Specifically, the objectives of the study are as follows:

(1) To develop an empirical technique based on underlying economic theory to measure the welfare changes associated with an environmental improvement. There has been a substantial research effort devoted to developing a rigorous and unambiguous definition and measure of changes in welfare at the theoretical level. However, there is a need to translate the theoretical concepts and definitions into usable, operational empirical techniques. The body of literature shows that even the available empirical estimations of benefits have been based on ad hoc procedures which have lacked adequate theoretical foundation.

(2) To apply the empirical technique to a small agricultural watershed in central Iowa, Bear Creek, to measure welfare improvement through proposed riparian zone and farm-field measures. The approach considers various econometric and analytical techniques to measure the willingness to pay for the improvement of water quality in Bear Creek watershed.

Plan of the Study

Chapter 1 includes the introduction to the study, the objectives, and the plan. Problems under review are outlined and describes the nature of the problem of agricultural pollution.

Chapter 2 review the literature on VBS including the nature of the buffer strips, how they function, and their impact, as a control mechanism of chemical runoff to ground and surface water sources. The review also includes the development of methodology to measure willingness to pay using dichotomous choice variables.

Chapter 3 reviews and summarizes the basic theory of welfare measurements while explaining the methodology. A comparison of the methodologies based on the market and nonmarket data and the underlying economic theory will be discussed. This chapter in general includes the theoretical core of the study and the application procedures. The purpose of this chapter is to provide basic premises and value judgements, that is underlying the economic concepts of benefits and the basic theory of the measurement of an economic welfare change. The theoretical basis of the Contingent Valuation (CV) methodology, advantages, biases, and disadvantages will be included. Further, some of the specific problems of the transition from basic theory to operational techniques are presented. In particular the problem associated with the estimation procedure using the Dichotomous Choice (DC) Contingent Valuation method will be discussed.

The question of how and under what conditions the benefits of environmental services can be estimated from the nonmarket data are answered in Chapter 4. The procedure would result in conceptually valid measures of the demand for environmental quality and of welfare change by nonmarket data and the survey techniques. This technique provides an estimate for willingness to pay (WTP) for improved water quality by the proposed measures. The analyses used to estimate WTP functions were Ordinary Least Square procedures, and the Maximum Likelihood Estimation (MLE) procedures such as Probit and Logit. The numerical integration procedure also was adopted to measure the area under Logit function and the

WTP values. Finally, WTP estimation obtained from various techniques are compared.

The summary and conclusions are presented in Chapter 5.

CHAPTER 2 LITERATURE REVIEW

Two main concepts included in this research are the vegetative buffer strip (VBS) and the contingent valuation (CV) using the dichotomous choice (DC) variables. Both are relatively new research concepts and, therefore, basic ideas will be explained while reviewing the literature.

Vegetative Buffer Strip

A riparian VBS is defined as a band of vegetation planted proximal to water sources such as streams, drainage ditches, and rivers. A vegetated band can consist of perennial grasses, shrubs, and tree species all with vigorous growth characteristics, and all purposefully established parallel to waterways along one or both banks. A VBS generally is located down slope from cropland or animal production facilities. The two primary objectives of the VBS are (1) to provide localized erosion protection, and (2) to filter nutrients, sediment, and other chemical pollutants from runoff. Additional but secondary objectives may include establishing a VBS to enhance fishing and wildlife habitats and to provide aesthetic and other recreational benefits.

Runoff water passing through a VBS follows a meandering flow path around plant stems, causing suspended sediment to be deposited (Tollner et al. 1976). Further, these meandering water paths allow more time for the infiltration of water within the soil in the strip, thereby reducing the NPS pollution entering the waterway directly. In the agricultural landscape, sediment is the most common and easily identifiable NPS pollution. Sediment entering waterways reduces or blocks the penetration of sunlight, adversely affecting the growth and reproduction of beneficial aquatic plants. Sediment also interferes with the feeding and reproduction of bottom-dwelling fish and aquatic insects, thus weakening the food chain.

Wilson (1967) indicated that sediment can be controlled by a grass filter strip. Further, he mentioned that the grass filters are effective in reducing clay-sized particle sediment loads. Clay is considered to be the mineral component of sediment that is effective in transporting soil-absorbed chemicals (Young et al. 1976). The effectiveness of the filtering action of the grass strip also depends on the upland treatment of the land. A great deal of research and effort have been expended to develop and implement farming systems that help control soil erosion.

Studies indicate that total soil volume lost is less for interrill erosion than for rill areas (Gilley et al. 1987). The flow from rill channels has a more concentrated flow, which enables more available energy to transport both suspended sediment and bed load. Some tillage practices can increase the rill erosion and, therefore, upland treatment is important for buffer strip effectiveness (Gilley et al. 1987).

Tollner et al. (1977) demonstrated that erect tall grass would have a greater sediment-trapping capacity than shorter more pliant grass using a vegetated medium to simulate physical condition factors. Dillaha et al. (1989) observed poor performance of a grass strip on steep slopes, causing the vegetation to suffer considerable loss of filter function. The VBS as filters work well in flatter areas, but sediment deposition tended to build up levees that directed flow into concentrated channels. Dillaha et al. (1989) concluded that a filter strip can effectively remove sediment if flow is not too steep, and if the strip is not filled by previous sediment deposition.

Four Functions of a VBS

The VBS has been shown to be an effective best management practice for the control of some nonpoint source pollutants, especially sediment and sediment-bound contaminants. Various studies have investigated the effectiveness of VBS for sediment removal from strip mine runoff, nutrient and solids removal from feedlot runoff, and the treatment of municipal wastewaters (Clinnick 1984; Dillaha et al. 1989). Vegetation retards the velocity and reduces the transport capacity of sediment-laden flow, which results in deposition. The major difference between flow in an open channel and shallow flow through a vegetative media is that a large portion of the total drag in the grass media is dissipated by the grass.

The filter function of the VBS can reduce phosphorus, because about 80 percent of available phosphorus is bonded to the small soil particles that comprise the sediment (Welsch 1991). Sediment and phosphorus are two of the major pollutants associated with surface runoff from areas of concentrated livestock activity, in addition to agricultural chemical pollution. A majority of the phosphorous in runoff from manure areas usually is bound to sediment, which can be removed by the deposition process. Ammonium, also bonded to sediment, can be filtered out in the same way. The filter action becomes less effective if sediment continues to accumulate. A VBS can serve as both short-term and long-term nutrient filters and sinks if trees are harvested periodically to ensure a net uptake of nutrients.

Alberts et al. (1981) found that nutrients leaving a 2.7m long strip with 50 percent residue cover were reduced by 70 percent relative to the filter strip entry. The results show that both sediment and nutrients in the water runoff were reduced by passage through a grass filter strip. Aull et al. (1980) reported that the runoff from fields containing the VBS showed significantly lower loads of five common water pollutants than did the runoff from a similar field without a VBS. Most notably, statistically significant differences in the concentrations of total solids, BOD_5, COD, TKN, NO_3-N and total PO_4-P were detected in the field runoff as a result of the filter performances. A study of riparian peatlands of a forested watershed in Minnesota revealed that 36-60 percent of all annual nutrient inputs were retained in the streamside zone (Verry and Timmons 1982).

The chemical and biological processes occurring within cause the buffer strip to function as a transformer. The transforming process generally changes the chemical composition of the compound. Some experiments reveal that the oxygenated soil conditions within the filter strip facilitate bacteria and fungi, which convert nitrogen in the runoff water into mineral forms (Welsch 1991). Plants and bacteria, in general, synthesize these mineral forms into proteins. Further, denitrifying bacteria convert dissolved nitrogen into various nitrogen gasses, which return to the atmosphere (Welsch 1991). The amount of nitrogen in water sources can be reduced up to 20 percent by passing through the VBS.

A VBS can transform toxic chemicals such as pesticides to nontoxic forms through microbial decomposition, oxidation, reduction and other biodegrading forces at work in the soil and litter of the VBS. Asmussen et al. (1977) reported a reduction of 2,4-D concentration by observing sediment loss, infiltration of water, and absorption of organic matter by a VBS.

Trees, which can be part of a VBS, function as a sink where nutrients are absorbed and sequestered in plant tissues. Some research studies indicate that 25 percent of nitrogen removed by trees is assimilated in tree growth and is stored in woody tissues (Welsch 1991). Trees serve as a source of energy for the stream in the form of dissolved carbon compounds and particulate organic detritus, which represents 75 percent of the organic food base consumed by water-dwelling plants and animals.

Determination of the best width of a VBS depends on various factors pertaining to the particular site. It seems that a strip 30m wide on either side of a stream provides adequate protection to the stream environment (Clinnick 1984). Buffer strip length of 36m appear to be sufficient to reduce concentrations of both nutrients and microorganisms to acceptable levels in feedlot runoff from summer rain storms (Young et al. 1980). A 20m width may be considered satisfactory in selected situations, for example, where soils are highly permeable and slopes are less than 30 percent (Clinnick 1984). Clinnick has reported many references concerning different widths and extends of VBS for differing soil types, geology, and slopes. According to Dillaha et al. (1989) two 9.1m and 4.6m VBSs with shallow, uniform flow removed an average of 84 percent and 70 percent of the incoming suspended solids, 79 percent and 61 percent of incoming phosphorus, and 73 percent and 54 percent of incoming nitrogen, respectively. Observation of existing VBS on farms showed that they are not likely to be as effective as experimental ones because of problems associated with flow concentrations.

Discrete Choice Models

Since the work of Bishop and Heberlein (1979), a number of CV experiments have occurred entailing discrete responses, which are analyzed by MLE procedures or similar approaches. In a study of goose hunting in central Wisconsin, they have evaluated outdoor recreation with the CV approach using two distinct experiments. A hypothetical market consisting of a sample of 353 hunters was interviewed to obtain a willingness to sell (WTS) value for their hunting permits, and their willingness to pay (WTP) value to obtain a permit.

Alternatively, using a simulator market experiment, they sent a real offer to a different sample of 237 hunters to buy their permits for a specified price. In both experiments, they have analyzed the individual responses with a logit model to derive an estimate of the average consumer surplus (CS) from a hunting permit. In previous approaches, whether to the iterative bidding or direct payment method, questions with continuous responses were included, which were analyzed using regression techniques. Similar attempts have been made by Loehman et al. (1981), and Desvousgas et al. (1983) using discrete responses and Logit and Probit techniques. Bishop et al. (1983) further analyzed the same data and found that in discrete-choice cases the price variable was the only one that was always significant in predicting both WTP and WTS. The main drawback of these procedures is that they are not exactly compatible with the utility theory.

Hanemann (1984) made a significant contribution in discrete response analysis by addressing the issue of how the Logit models should be formulated to be consistent with the hypothesis of utility maximization, and how measures of compensating and equivalent surplus should be derived from the fitted models. Hanemann suggested a procedure that explicitly recognizes the utility-maximizing choices underlying individual responses. He further introduced a stochastic component directly into the utility function. For any individual, the true compensating and equivalent surpluses are random variables. Hanemann considered three possible welfare measures. Two of those considered, the mean and median of the distribution of the true compensating or equivalent surpluses, are shown to be invariant with respect to an arbitrary monotonic transformation of the random utility function. Using data collected by Bishop and Haberlein (1979), he formulated a Logit model to be compatible with the assumption that the experimental responses are the outcome of a utility-maximizing choice. Further, he showed how the value of a permit can be derived from the fitted binary response models. Finally, he compared the results with those obtained by Bishop and Haberlein. The results further point out that many estimates reflect differences in the type of the experiment and the method of statistical estimation, as well as the choice of welfare measures. He preferred the MLE to the GLS procedures used by the Bishop and Haberlein in the presence of zero proportions of acceptances for some offers. If there are any differences in responses, it can be proved only by taking some given utility model and deriving the resulting statistical results for the responses.

Sellar et al.(1985) compared the results of travel cost (TC) and contingent valuation (CV) methods and pointed out that the TC provides an estimation of Marshallian consumer surplus (MCS) whereas CV provides an estimation of Hicksian equivalent measure of welfare change. However, when the income effect is small, the difference becomes narrower. In their study, they found that the income effect is small given that the value associated with recreational boating contributes very little to the boater's total income. The study was conducted on four lakes in east Texas using an open-ended CV model. The bid curve was estimated using linear, linear with a squared term in Q, and a double logrithemic form. Differentiating the bid curve, they have obtained an inverse Hicksian demand curve for each lake. This demand curve is unique to the reference welfare level of the boater given in the posited contingent market, nonparticipation. The area under this curve to the left of the mean number of visits provides a Hicksian equivalent measure of welfare change for the average boater. The closed-ended format of the CV method used the binary response model to analyze the data. Data were collected using a mail survey conducted for 2000 sample of boat owners. The response rate of the survey was 62.4 percent.

To find the accuracy rate, respondents were asked to rate the accuracy of their value response; this measure is unique to this analysis. The demand curve estimated for the two CV methods reveals that the open-ended procedure yields a lower measure of CS than the closed-ended procedure. The difference is due to the location of two demand curves. There seemed to be some problems with the open-ended format in that boaters did not appear to reveal their true value for the lakes through the CV market situation. However, the closed-ended format yields a more reliable estimation for the CS.

The analysis used the offered threshold value t_i as a primary explanatory variable in the binary discrete choice model. The fitted choice probabilities are interpreted as the upper tail of the distribution of valuation. In the second step, these cumulative probabilities are used to estimate the expected value of the resource in question. In this case, the truncation bias is potentially serious because the offered amounts always have an upper limit.

Sellar et al. (1986) addressed the issue of proper specification of the Logit model for estimation of nonmarket commodity demand. They have further illustrated the implications of the choice of functional form. An empirical example was used to illustrate the argument using the data collected from Texas. The basic referendum voting-style approach involved asking whether or not the consumer would be willing to pay some specific amount of money for recreational boating. The consumer's decision involved a dichotomous choice, which was analyzed by arraying probabilities of positive responses at specific amounts and by analyzing quantal choice procedures. They have further argued that when the CV procedures involve asking for noniterative quantal choices, the Logit model is applicable. However, simple linear specification for the explanatory variables in the Logit model is inappropriate because such specification may not be consistent with the implications of consumer theory. Therefore, an alternative log-linear form is proposed. It was shown under what condition it is consistent with economic theory. A linear specification was found to be inappropriate by implying an upward sloping demand curve for the Texas data. Among others, a log-linear form was used in terms of meeting the restrictions suggested by the economic theory. The estimated demand curve indicates that the choice of a particular functional form can have an important impact on the mean WTP measured from the model. The arguments offered regarding the functional form seem very appropriate as does the alternative approach adopted in this analysis, in which the probabilities are left in the form of fitted algebraic expressions. The marginal expected values are determined by the numerical integration over a continuum of values from zero to the maximum level of X variable. However, a hazard of truncation bias remains.

Cameron et al. (1987) developed a MLE procedure, which exercises the variation in the threshold values to allow direct and separate point estimates of regression. This procedure eliminates truncation bias. They formulated an ideal model for the demand for recreational fishing days based on formal micro-economic theory. The data used consisted of 416 responses to an in-person survey of recreational fishermen conducted on the south coast of British Columbia, Canada. Respondents were asked whether they still would have gone fishing that day were the cost of the day's trip some pre-specified number of dollars higher. This procedure is known as the threshold offer. The analysis estimated the desired coefficients and approximate asymptotic standard errors using Probit regression algorithm. The Probit procedure can be implemented either through (1) conventional Probit estimation followed by transformation of the parameter estimation and calculation of approximate asymptotic standard errors, or (2) directly by maximization of the likelihood function. They also investigated the influence of each variable for WTP values. In the log-linear model, heterogeneity among the anglers will result in differing values across observations for each derivative. Also provided was the exogenously weighted means of these derivatives across all respondents. One of the advantages of this approach is the ability to easily determine the derivatives of total value with respect to each explanatory variable. For this example, overall mean WTP was estimated as $48.83. In general, they emphasized that analyses using CV data need no longer be limited to the estimation of an approximate marginal distribution of valuation over an entire sample. Instead, it is possible to isolate the impact upon resource valuation due to specific site amenities and individual user's characteristics.

Boyle et al. (1988) compared three commonly used techniques of asking CV questions: iterative bidding, payment cards, and dichotomous choice (DC). The results reveals that no single technique is superior to any other and each has its own strengths and weaknesses. In this experiment, only iterative bidding and payment cards were used and each respondent participated in only one treatment. The bidding treatment was designed in order to obtain DC values from the same data set. Other CV studies suggest that interviewers can influence respondents' stated values; this study tested the interviewer bias in the values estimated. Interviewers and treatments were rotated at each location to differentiate between interviewer and location effects. Thus, comparisons across interviewers occurred while treatment and interview locations remained constant. Data for the analyses were collected by personal interviews with canoeists and boaters as they completed their trips on the lower Wisconsin River during summer 1982. A total of 502 people were interviewed but 85 refused to participate. The mean WTP for iterative bidding was $29.82; for the payment card, it was $29.36. DC values were derived using the Logit function estimated by the initial bids and the respondents' answer to them. Evaluating this function at the sample mean leads to a conditional estimate of WTP value of $91.76. The estimated mean was derived by integrating one minus the estimated Logit CDF over offers from zero to infinity. The estimated Logit function should be normalized to derive a proper expected value when the area of integration is truncated. Normalization procedure is necessary for the CDF to adhere to the property that the area under its probability density function is equal to one. Thus, the resulting estimate of WTP under normalization procedure was found to be $18.88, which is more reasonable. DC is the easiest technique to administer in a survey setting.

Cameron (1988) challenged Hanemann (1984) and Seller et al. (1986) for utilization of Logit models to estimate the value of nonmarket resources from the closed-ended (referendum) survey set. The methodology presented in this paper is different than strategies described in the previous two papers. The major difference in close-ended data is that the offered threshold amounts are varied across respondents, whereas ordinary Logit models have a constant zero threshold. It also emphasized that referendum data are not discrete-choice data in the conventional sense. Maddala (1983) provides a taxonomy of distinct types of discrete regression models, in which referendum data are just a related family. The normality assumption in discrete-choice based models is no longer valid, hence it depends on Logit models, which are relatively more expensive. All censored or discrete-choice models require the computation of cumulative densities. For Logit models, which are based on standard logistic distribution, the cumulative density does have a closed form. The density is simply a ratio of exponentiated quantities, which are cheap and easy to calculate. The shape of these two distributions, standard normal and standard logistic, are identical except for the thicker tail of the standard logistic distribution. Therefore, the logistic-based model provides a very convenient and accurate approximation of the normal-based models. In this paper, the author reviewed competing interpretations of Logit models and described the likelihood function for use with referendum data under the logistic assumption. Further, normal and logistic distribution-based models were examined using a subset of the data from previous study to determine whether those models would yield similar inferences. Finally, he emphasized why the traditional random utility maximization approach is unnecessary with referendum data. Avoiding the utility function approach, it was shown that parameters and standard errors for utility theoretic Hicksian demand curve can be extracted directly. Estimated demand functions need not be limited to those corresponding to the linear in parameters of utility-different specifications which can be handled by packaged Logit programs.

Boyle et al. (1988) pointed out technical errors made by Sellar et al. (1985), which lead to misstated closed-ended estimates of WTP. They examined the erroneous specification of Seller's equation, which lead to incorrect expected WTP. Thus, the estimated CDF have neglected the mass distribution of the upper tail, resulting in under-estimated value. The paper suggests that the estimated CDF should be normalized prior to estimating the expected values. The biggest argument was that in Seller's paper results were obtained from general statistical properties and that these hold regardless of whether a Logit model or Probit model or any other continuous distribution is used. As Hanemann (1984) suggested, the median of the estimated distribution can be used as an alternative welfare measure for the fat tail problem. Further, Hanemann suggests that the median is desirable from an empirical perspective because it is relatively robust with respect to marginal changes in the shape of an estimated distribution. However, Boyle et al. suggest that the median has an undesirable feature in that it does not fully reflect the values of individuals who have the most to gain or lose, as the case may be, from the proposed policy. For example, if the estimated distribution was skewed toward high values, the median would be less than the expected value. The main disadvantage of using median is that, as a welfare measure it may nullify the flexibility of the model. Thus, for CV studies they are concerned with the entire range of the estimated distribution since expected values are computed by integrating the area under the curve. Also suggested is a procedure to obtain a preliminary estimate of the distribution of values. This can be done using a well-designed pretest survey to construct an empirical CDF and subsequent analysis. This process ensures that the selected observations are balanced between the tails of the distribution and it clusters the majority of the offers around the median.

Bowker and Stoll (1988) applied the DC form of CV to quantify individuals, economic surplus associated with preservation of the crane resources. This unique application of the DC approach to an endangered species, is consistent with the utility theory. Further following Hannemann, economic surplus is estimated at the sample median and mean. This WTP function represents the probability that an individual will respond positively to paying a specified amount for the whooping crane resources. The offer, according to the authors, is an argument of the utility difference. The parameters of the binary response models may be estimated using GLS or MLE. In this study, MLE procedure is used and both the Logit and Probit model is estimated. The survey is administered in the winter/spring of 1983 in Arkansas and Texas. The mailed and on-site surveys are carefully administered according to the accepted standards. The MLE of the Logit and Probit models confirmed prior expectations. The two models differed little in terms of summary statistics and parameter significance for any given specification of the utility difference. The mean values are calculated by numerically integrating the area under each estimated WTP functions over the range of the offer amounts. They found the mean equivalent surplus measures to be considerably higher than the medians in all but one case. This occurred despite the downward bias on means caused by truncating the range of integration at the highest offer. They also found that doubling and tripling the range of integration increased the means as much as 75 percent. In this application the truncation rule chosen has considerably less effect on utility theoretic specification than on logarithmic specification. Notably, the calculated results relatively invariant to both

Logit and Probit approaches. An increased probability of offer acceptance was due basically to income and wildlife-oriented organization membership. Mean WTP was estimated to be between $21 to $149, depending on the level of truncation used and functional specification. It was found that the majority of estimates were $70 or less. Mail survey respondents' WTP ranged from $21 to $70. The authors have indicated the sensitivity of estimates of WTP to the issues of functional form, truncation, and the statistical estimator of WTP adopted, such as mean or median.

Shultz and Lindsay (1990) used nonlinear MLE (Logit model) to analyze the relationship between the DC responses to WTP and the independent socioeconomic variables. Many ground water protection strategies have accurate data on cost aspects, but the economic value the public places on ground water protection is often unknown. An attempt was made in this study to demonstrate a methodology to estimate economic value. A questionnaire was mailed to 600 Dower, New Hampshire property owners to elicit household total WTP for a hypothetical ground water protection plan. As Cameron (1987) suggested, the authors have used an alternative method of determining the effect of a specific independent variable on WTP while holding all other variables constant. This procedure involves the transformation of the logistic WTP equation by dividing the constant term and other slope coefficients by the coefficient of the dollar bid. This transformed equation is equivalent to OLS estimation in that unit changes can be used as marginal elasticities. By following an already established CV procedure, it was estimated that the property owners' median WTP for a ground water protection plan in Dower is $40 annually. Using a conservative aggregation procedure, it was further estimated that Dower property owners would be WTP over $100,000 annually in extra property taxes for the plan. The Logit regression procedure was further extended to determine the specific socio-economic characteristics that influence the WTP values.

Duffield and Patterson (1991) addressed the problem of variance estimation and sample allocation in DC CV methods. First, they demonstrated the use of bootstrapping to estimate the variance of the truncated mean. They then considered a nonparametric estimator for the truncated mean. This estimator follows from the same utility theoretic behavior that is applied in the standard Logit or Probit applications. The only difference is that no specific functional form is assumed for the underlying WTP distribution. They also consider the theoretical relationship between the nonparametric and parametric models. In using the nonparametric model, the functional form of the cumulative distribution function of WTP is not specified but is, instead, estimated by a piecewise linear function. The nonparametric approach leads to an alternative estimator for the truncated mean, which is simply the area under the piecewise linear approximation from 0 to T. They have compared the estimated truncated means from the Logit model with the nonparametric estimates for several data sets and found them generally to be in close agreement. In fact, they have argued, given adequate sample sizes, the large differences between the two methods reflect a lack of appropriateness of the chosen functional form. Standard errors for the Logit and nonparametric truncated means also were very similar. The nonparametric approach is based on the same utility theoretic motivation as the parametric Logit or Probit models, the only difference being that the latter assume a functional form for the distribution of the WTP function.

Cooper and Loomis (1992) addressed the sensitivity of DC CV models based WTP measures to the sample design and to alternative measures of WTP. Their paper focuses on the sensitivity of mean WTP with respect to changes in the size of the bid vector both analytically and empirically. Specifically, a sensitivity analysis was conducted by removing bid values from both the upper and lower ranges and the effects of specifying wider bid intervals was examined. For the empirical estimation, responses to ten WTP questions from three different surveys were analyzed. Using an estimator of WTP that allows for both negative value and positive value, WTP was reestimated for each question with up to the four lowest values removed, and with up to the four highest values removed. In addition, WTP was reestimated with every other bid value removed. The large decrease in mean WTP using both negative and positive values with a truncation of the upper bid range tends to suggest that the tail of the distribution is "fat". In fact, an empirical comparison of Logit distribution for several data sets disclosed a positive relationship between the fatness of the tail of the distribution and the impact on WTP of removing the upper bids. The effect on mean WTP of a truncation of the lower bid values is relatively small. Increasing the intervals between the bid values had rather unpredictable behavior on mean WTP. The results suggests the advantage of having more care on determining the sample design.

CHAPTER 3 METHODOLOGY

The welfare of a society depends on the satisfaction levels of all its citizens. In general terms, welfare economics is concerned with the relationship between people's well-being and the means and ways the productive resources available to society are used. One purpose of the economic system is to satisfy people's needs and wants, given the distribution of property and other productive resources, among the people. This is known as the efficiency. Equity, on the other hand, refers to concerns that people have about the distribution of wealth and income. Mechanisms such as taxes and various transfer programs can be effectively used to redistribute wealth. However, the attempt to incorporate distributional consideration into the environmental protection program fails to achieve substantial improvement in efficiency of resource allocation.

The history of welfare economics has been dominated by the notion of a Social Welfare Function (SWF) and the Production Possibility Frontier (PPF). The early definition of a SWF was simply the sum of the utility of the members of that society for the production of different combinations of goods (Mitchell and Carson 1989). Utility was assumed to be measurable in the cardinal sense, and comparable across individuals. PPF is a positive economic concept[1] depicting how production of one good could be traded off, in a technical sense, for the production of another good. According to this methodology, the optimal output of an economy has been determined at the point of tangency between the SWF and the PPF. However, in late 1930s, the theoretical basis of the SWF was challenged with rejection of the notion of cardinal utility across individuals, in favor of an ordinal definition of utility, with no comparability across individuals. Bergson (1938) and Samuelson (1947) have made an unsuccessful attempt to rebuild SWF in the framework of a new ordinal utility. The work of Arrow (1951) showed, however, that there was no nondictatorial way to aggregate preferences into a SWF that did not violate axioms of behavior and choice. Thus, the SWF plays no role today in Applied Welfare Economics. Modern welfare criterion is based on the weaker but ethically more neutral Pareto Optimality Criterion.

The Pareto Criterion can be used to measure efficient resource allocation, which takes the utility function as the measure of individual welfare. In simple terms, the resource

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[1]Economics can be divided into two branches, positive and normative (Stiglitz, 1986). Positive economics describes how the world works, while the normative (welfare aspects) explains how the world could work.

allocation that provides a bundle of goods and services, which is preferred to the previous bundle because it provides a higher utility to individuals, is said to increase the individual welfare. According to the Pareto Criterion, a resource allocation is efficient if it enables at least one person to achieve a higher level of utility while making no one worse off. Thus, a certain resource allocation is a gain in social efficiency if it makes someone better off and no one else worse off. The economy is socially efficient if no resource allocation can increase further social efficiency or the sum of all individual welfare. Social efficiency is concerned with performance of the entire economy, and is studied in the context of theories of producer and consumer behavior and market equilibrium.

Basic Welfare Analysis

The basic goal of this type of analysis is to establish that, in certain circumstances, competitive input and output markets ensure socially efficient resource allocation. Consider that there is an economy with N individuals who consume goods and services and supply productive inputs. The economy provides good j to the society. Consumption of good j by individual i is written as x_{ij}. Altogether, k inputs are used to produce goods. Thus, y_{ik} denotes supply of input k by the individual i. Thus, the ith individual's utility depends on both consumption of goods and supply of inputs.

$$U_i = (x_{i1}, \ldots, x_{ij}, y_{i1}, \ldots, y_{i1}, \ldots, y_{ik}) \qquad i = 1, \ldots, n \tag{3.1}$$

Tastes of individuals may vary from person to person, and an individual is denoted by the subscript i on utility function. A y_{ik} denotes mainly the kind of labor input supplied by people. The goods in the society are produced in accordance with the production function with available inputs. The production function for the jth good is

$$X_j = F_j(Y_{j1}, \ldots, Y_{jk}) \qquad j = 1, \ldots, m \tag{3.2}$$

where

X_j is the total production of good j.

Y_{jk} is the total amount of input k used to produce good j.

The total of good j produced must equal the total amount consumed by individual (i). Therefore,

$$X_j = \sum_{i=1}^{N} x_{ij} \qquad j = 1, \ldots, M \tag{3.3}$$

Similarly, the total of input k used by all firms must equal the total supplied by owners:

$$\sum_{j=1}^{M} Y_{jk} = \sum_{i=1}^{N} y_{ik} \qquad k = 1, \ldots, K \tag{3.4}$$

In this formulation, it is assumed that the indifference curves and isoquants do not touch the axis and that the inputs are not produced. Those assumptions are made only for expositional simplicity. The conditions for social efficiency of resource allocation now can be established. The first condition for socially efficient resource allocation can be written on as follows:

$$MRS_1(X_{1j}X_{j1}) = MRS_2(X_{2j}X_{21}) = \ldots = MRS_N(X_{Nj}X_{N1}) \qquad j,1 = 1, \ldots, M \tag{3.5}$$

where

MRS = Marginal Rate of Substitution, which is the slope of the indifference curve.

Equation (3.5) indicates that the consumption quantities must be such that everyone has the same MRS between each pair of commodities. This is a necessary condition if the allocation of fixed amounts of goods among the population is to be socially efficient. The condition for socially efficient input allocation is

$$MRT_1(x_jx_1) = MRT_2(x_jx_1) = \ldots = MRT_M(x_jx_1) \qquad j,1 = 1,\ldots,M \tag{3.6}$$

where

MRT = Marginal Rate of Transformation between commodity j and 1, which is the ratio of the marginal products of the inputs in two production activities.

Equation (3.6) indicates the condition for social efficiency that has to do with allocation of fixed input quantities among production activities. The MRT is the rate at which the output of one can be increased as the output of the other decreases when an input is transferred from the second to the first, keeping total uses of input in both activities constant.

The third condition, given in equation (3.7), ensures that the amount of products produced match consumer tastes.

$$MRS_i(x_{ij}x_{il}) = MRT_k(X_jX_l) \qquad i = 1,\ldots,N, \quad j,l = 1,\ldots,M \quad k = 1,\ldots,K \tag{3.7}$$

The left-hand side (LHS) of the equation is the rate of substitution of j for l by the consumer preferences, while the right-hand side is technical rate of substitution between j and l. The condition given in equation (3.7) must hold if resources are allocated so that no reallocation can make someone better off without making anyone else worse off.

The final condition ensures that the optimum amounts of input are supplied, that is

$$F_{jk}(Y_{j1},\ldots,Y_{jk}) = MRS_i(x_{ij},y_{ik}) \qquad i = 1,\ldots,N \quad j = 1,\ldots,M \quad k = 1,\ldots,K \tag{3.8}$$

where

F_{jk} = increase in production of j resulting from an increase of k, (marginal product of k due to product j)

These four conditions given above pertain to consumer tastes as embodied in the utility function (3.1), and the technology as embodied in the production function (3.2). In general, these conditions explain how input and output must be employed if the economy is to be socially efficient. In a competitive market, consumers would achieve efficiency by equating MRS to the ratio of product prices if they are utility maximizers.

$$MRT_i(x_{ij}x_{il}) = \frac{P_i}{P_j} \qquad i=1,\ldots,N \quad j,l=1,\ldots,M \tag{3.9}$$

where

P_i & P_j are prices of goods i & j

If firms are profit maximizers, they will equate their marginal rate of product transformations, marginal rate of technical substitution, and marginal products to the corresponding price ratios. Thus, for the products j,l, and input k, the condition is

$$P_jF_{jk}(Y_{j1},\ldots,Y_{jk}) = W_k, \quad P_lF_{lk}(Y_{l1},\ldots,Y_{lk}) = W_k \qquad j,l = 1,\ldots,M \quad k = 1,\ldots,K \tag{3.10}$$

In the equation (3.10), F_{jk} and F_{lk} denote marginal products of input k for producing j and l, and W_k denotes the market price of input k. Thus,

$$MRT_k(X_j,X_l) = \frac{F_{jk}}{F_{lk}} = \frac{P_l}{P_j} \tag{3.11}$$

If j and l both refer to commodities, then

$$MRTS_k(X_j,X_l) = \frac{P_l}{P_j} \tag{3.12}$$

If j and l both refer to factors of production, then

$$MP_{jl} = \frac{P_l}{P_j} \tag{3.13}$$

In a competitive equilibrium, consumer i maximizes utility with respect to the supply of input l owned equating the MRS between input supply and product consumed to the ratio of input price to the product prices.

$$MRS_i(x_{ij}Y_{ik}) = \frac{W_k}{P_j} \tag{3.14}$$

Equating the two equations (3.14) and (3.10) produces the condition that is equivalent to equation (3.8).

$$\frac{P_j}{P_j} F_{jk} \ (Y_{j1},\ldots,Y_{jk}) = \frac{W_k}{P_j} = MRS_i(x_{ij},y_{ik})$$

Equation (3.10) holds for all j,k and l. Further, it must hold when the two equations refer to the same good, but different input. If we consider the good is j and the inputs are k and l the result is a follows:

$$P_jF_{jk} = W_k, \qquad P_jF_{jl} = W_l \tag{3.15}$$

Dividing each equation by the marginal product produces the following condition:

$$\frac{W_k}{F_{jk}} = P_j = \frac{W_l}{F_{jl}} \qquad j=1,\ldots,M \quad k,l=1,\ldots,K \tag{3.16}$$

This indicates that output increases per unit of input, which is the marginal product given in the denominators. On the other hand, cost increases per unit of increased inputs are given in numerators. Therefore, the left-hand side (LHS) and right-hand side (RHS) of equation (3.16) are marginal production costs. That marginal product equals product price is an implication of competitive profit maximization and of socially efficient resource allocation.

In many real-world situations, however, many circumstances exist in which private gain does not entail socially efficient resource allocation. As a result, private markets do not provide socially efficient resource allocation, which will be referred to as market failure. Such is the case concerning water quality deterioration from agricultural chemicals, which leads to market failure as do many other environmental problems. These external diseconomies affect people's welfare yet do not go through ordinary market transactions described above. If input and output markets are competitive, those input-output prices reflect as opportunity costs. The general criticism of the competitive market is that the marginal social cost of production exceeds the value of the product at the equilibrium output and, therefore, leads to overproduction. Thus, if an economic activity affects the utility function, then externality occurs resulting in resource misallocation. In theory, any resource allocation that is off the contract curve is socially inefficient. Thus, a different resource allocation would make some people better off without making others worse off.

The major problem in the nature of NPS pollution is the assignment of pollution rights. In the case of agricultural pollution, the issue of pollution rights does not apply to farmers. Unlike the factory owner who has rights to pollute water, the farmer does not apply fertilizer with the intention or perhaps even the knowledge of polluting water resources. People using surface and ground water resources downstream have the right to use clean water. However, farmers upstream do not intend to pollute water sources by applying chemical fertilizers. If water users have a right to clean water, then farmers must compensate the users for their action. This issue of pollution rights is about equity and the distribution of intangible property. Therefore, the pollution rights in NPS pollution are disputed or unresolved, which leads to inefficiency in resource allocation. If the issue of pollution rights is resolved, the parties can proceed with an agreement that can result in a socially efficient resource allocation.

In Iowa, as in many parts of the eastern USA, a basic characteristic of the water resources is that they are part of the public domain. This means that, at least in the absence of restrictions, anyone can use or misuse water freely. Pollution rights are difficult to define in water resources since those sources of pollutions are precisely unidentified. This is the problem with many environmental activities that are inherited to public goods. A public good is a commodity or service that requires resources to produce, but once produced, additional people can consume the good without additional cost.

Water sources polluted by agricultural activities require additional resources to clean up. Once cleaned, the public good (clean water) can be used by everyone at no added cost. The problem of NPS agricultural pollution abatement relating to surface and ground water involves cleaning activities. If the water sources are in the public domain, each person in society should agree to pay a share of the cost. The problem arises if any person declines to pay a share of cost. This could arise due to the so-called free rider problem, in which one individual relies on the public good supplied by another.

Further, free riding relates to the failure of individuals to reveal their true preferences for the public good through their contribution (Cornes and Sandler 1989).

On the other hand, the revelation of demand also is difficult with respect to public goods. Everyone tries to understate their demands for clean water if a share of the cost is to be assessed on the basis of demand. The government must intervene to achieve an optimum ambient water quality in such situations. This is inevitable because quality water is a public good and everyone is affected by water quality. Government intervention, however, does not completely eliminate the problem. It would, perhaps, solve the financing problem by levying taxes and effluent fees, for example.

The notion of benefits from public goods is somewhat different from other types of benefits. Many people may consume a particular public good; however, one person's consumption does not preclude another person's consumption. Furthermore, it is difficult to identify beneficiaries for environmental goods. The total benefits from a public goods are the sum of the benefits to all who consume the public good. Thus, the measurement of benefits associated with public goods seems somewhat difficult relative to the estimation of costs.

The Concept of Benefits and Welfare Change

A change in water quality can affect the population's welfare through (1) changes in income and prices individuals pay for goods, (2) changes in the quantities of nonmarket goods, and (3) the changes in prices received for factors of production. Nonmarket commodities often is assumed to be worth zero, because of its zero market value. Therefore, the section three mainly consider measurement of nonmarket benefits.

Changes in Prices and Income

Water in many places in the world is priced and sold as a normal good whereby the optimum production equates marginal cost and revenue. This implies that the optimum production is the amount for which consumers are willing to pay the increased cost of the last unit produced. The consumer's utility shown in the equation (3.1) is affected not only by goods consumed and input supplied but by a public good, Q, water quality.

$$U_i = U_i(x_{i1},\ldots,x_{ij},y_{i1},\ldots,y_{ik},Q) \qquad i = 1,\ldots,N \qquad (3.17)$$

Q denotes water quality affected by all consumers equally. The attempt is to improve Q using various inputs

$$Q = f(Y_{q1}, \ldots, Y_{qk}) \tag{3.18}$$

Y_{qk} denotes the amount of input k devoted to water quality improvement. For example, an input could be a VBS or any other soil conservation measure adopted to control agricultural pollution. Thus, optimum resource allocation, including the public good Q is2

$$\sum_{i=1}^{N} MRS_i(x_{ij}, Q) = MRT_k(X_j, Q) \quad j=1,\ldots,M \quad k=1,\ldots,K \tag{3.19}$$

This rule of optimum public goods production was first shown by Samuelson (1954). Note that the equation (3.19) is analogous to (3.7) for a private good. However, this is difficult to estimate because the MRS between public goods and private goods for all consumers are unknown. In addition, the government is unaware of the consumer's utility function and, therefore, cannot estimate equation (3.19) directly and use it for planning public goods production.

To estimate public goods benefits, it is necessary to derive market demand equations for goods and services shown in utility function (3.1). For convenience, we simply ignore input supply side of utility maximization.

$$U_i = U_i(x_{i1},\ldots,x_{ij},Q) \tag{3.20}$$

Consumer i maximizes (3.20) subject to his/her budget, or total income, constraint.

$$\sum_{j=1}^{M} P_j X_{ij} + P_q Q_i = I_i \tag{3.21}$$

where

I_i = total income of consumer i

P_j = price of the jth consumer good

P_q = price of a unit of water quality

Q_i = water quality demanded by consumer i.

Thus, the lagrangian function,

$$L = U_i(x_{i1},\ldots,x_{ij},Q) + \lambda(I_i - \sum_{j=1}^{M} P_j X_{ij} + P_q Q_i) \tag{3.22}$$

The set of first-order conditions for the constrained maximization of U_i solves the condition for the consumer's decision variables $x_{i1},\ldots,x_{ij}$ and Q_i. These conditions lead to a solution to a set of consumer goods and the demand equation for water quality Q.

The ordinary market demand equation for each consumer is given by

$$x_{ij} = f_{iq}(P, P_q, I_i) \quad i=1,\ldots,N \quad j=1,\ldots,M \tag{3.23}$$

and the water quality demand equation for each consumer is given by

$$Q_i = f_{iq}(P, P_q, I_i) \quad i=1,\ldots,N \tag{3.24}$$

where

P = set of prices for other goods, P_1 to P_j

P_q = amount consumer i is WTP per unit of quality water when Q_i units are consumed.

Clean water quality is assumed to be a normal good. The water quality demand equation (3.24) is a function of P_q, P, and income I. Further, it is an increasing function of income and a downward sloping demand equation.

The compensated demand curve (CDC) can be obtained using the utility maximization procedures. The resulting demand equations are shown below.

$$x_{ij}^* = f_{ij}(P^*, P_q^*, I_i^*) \tag{3.25}$$

The quality water demand equation is

$$Q_i^* = f_{iq}(P^*, P_q^*, I_i^*) \tag{3.26}$$

The water quality demand equation is shown in Figure 3.1. The benefit of a decrease in the price of a unit of quality water to i is that it reduces the expenditure necessary to achieve initial utility level U_i^* obtained at the higher price P_q^*. Thus, the impact is a movement down f_{iq} and, therefore, an increase in utility as a result of the reduction in cost of the quantities $x_{i1}^*,\ldots,x_{im}^*$ and Q_i^*, and in the money available to consume other commodities. The price of a unit of quality water drops from P_q^* and the utility level U_i^* could be maintained if consumer i's income was reduced from I_i^*. The reduction of income would be generally greater if the drop of price is significant. The CDC refers to the demand curve along which income is changed to achieve the original utility

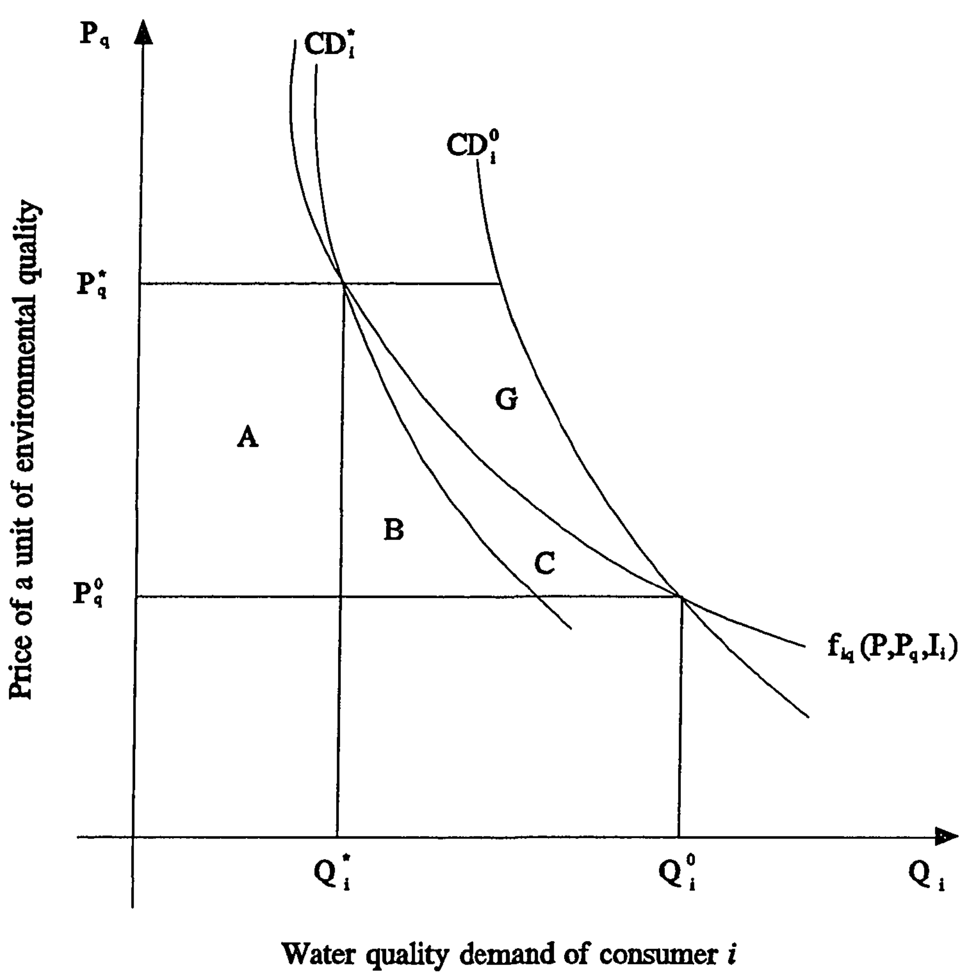

Figure 3.1. Compensated quality water demand equation

level. The CDC is downward sloping since all points on a CDC are on the same indifference curve. The substitution effect of a price change is the movement along the CDC, which generally increases the demand for a product whose price has fallen. Therefore, the CDC provides a measure of reduced expenditure needed to achieve the original utility level. The reduced expenditure from a price decrease is shown in Figure 3.1 by the areas of A,B,C, and G. These areas are known as equivalent variation (EV). The EV measure depends on the change in income that would lead to the same utility level as the change in prices, given the original price. Thus, EV is the income change equivalent to the welfare gain due to the price change. The EV measure also has been described as the minimum lump sum payment the individual would have to receive to induce him/her to voluntarily forego the opportunity to purchase at the new price. Except for a price increase, EV is the maximum amount the individual would be WTP to avoid the change of price.

On the other hand, the expenditure saving is referred to as the compensating variation (CV), which is the area of A and B shown in Figure 3.1. This measure depends on the compensating payment or offsetting change in income necessary to make the individual indifferent to the difference between the original and new price. The measure CV often is interpreted as the maximum amount that the individual would be WTP for the opportunity to consume at the new price. In general the CV is the gain in benefits individual i receives from a price decrease, while the EV is the loss of benefits from a price increase.

As seen in equations (3.20) and (3.24), utility maximization for an individual leads to a set of ordinary or Marshallian demand functions. Using the dual of this problem, we can obtain the expenditure function following a constrained optimization procedure.

$$\begin{aligned} &\text{Min} \sum_{j=1}^{M} P_j X_{ij} + P_q Q_i \\ \text{s.t.} \quad &U_i = U_i(x_{i1}, \ldots, x_{ij}, Q) = U^0 \end{aligned} \qquad (3.27)$$

The solution to this problem is the expenditure function, which is the minimum dollar expenditure necessary to achieve a specified utility level given a market price and the price of water quality.

$$E = E(P, Q, U^0) \qquad (3.28)$$

where

E = dollar amount of expenditure

P = vector of prices, $P=P_j,\ldots,P_m,P_q$

U^0 = specified utility level

Q = environmental good

We have derived the demand equation and the environmental demand equation conditional to prices and money income using equations (3.25) and (3.26). The solution to equation (3.27) similarly yields a set of demand functions and environmental demand equations conditional to prices and utility as follows:

$$x_{ij}^* = x_{ij}(P^*, P_q^*, U^0) \tag{3.29}$$

and the environmental demand equation,

$$Q_i^* = Q_i(P^*, P_q^*, U^0) \tag{3.30}$$

Equation (3.30) is known as Hicks Compensated Demand (HCD). This indicates the quantities consumed at various prices, assuming that income is compensated, so that utility is held constant at U^0 level. The EV and CV measures of a welfare change due to water quality can be derived using these demand functions.

The third benefit measure, known as consumer surplus (CS), was first introduced by Alfred Marshall (1949). Marshallian consumer surplus (MCS) is the area to the left of the demand curve and above the price line in Figure 3.1. The change of the MCS indicated by the areas of A,B, and C. The MCS value lies between the two Hicksian measures of CV and EV. CS is an area under an ordinary demand curve, which also is the WTP value. The utility an individual derives from consuming a good or service is the amount the individual would be WTP for the good above the price paid. The ordinary demand curve can be estimated using market data, but the CDC requires more sophisticated estimation procedures. Public goods are primarily nonmarketable and, therefore, estimation of demand or WTP using direct methods is very difficult.

The change of CS is a good approximation of social benefit estimation. The effect of a decline in P_q measured along the CD_i^* in figure 3.1 is known as the substitution effect, that is, the effect of a decrease in P_q on demand for Q_i when income is adjusted to hold utility constant at U_i^*. The difference between the area under an income compensated HDC and that area under an ordinary MDC depends on the size of the income effects accompanying the price changes associated with movements along the ordinary demand curve. This considers the effect on demand for Q of an increase in income, holding all prices constant.

To summarize the comparison of measures to this point, the CV and EV measure different concepts and neither is observable even from market data. The EV does not provide a unique measure of welfare change when it involves change in more than one price. The CS lies between CV and EV measures and is equal to the CV and EV in the special case of zero income effect. The basic differences depend on the income elasticity of demand for the good in question and CS as a percentage of income or expenditure.

Welfare Effect of a Quantity Change

An important characteristic of some environmental goods is that they are available in fixed quantities at a zero price. The CV and EV measures of welfare change of improved water quality can be measured using the change of quantities. Assume Q is the quality water and x_1 is the private composite good, which also is used as a numeraire good. The vertical line Q' shown in Figure 3.2 denotes the initial fixed quantities of water quality. The horizontal line shows the level of consumption of x_1 using income I and given price P_1.

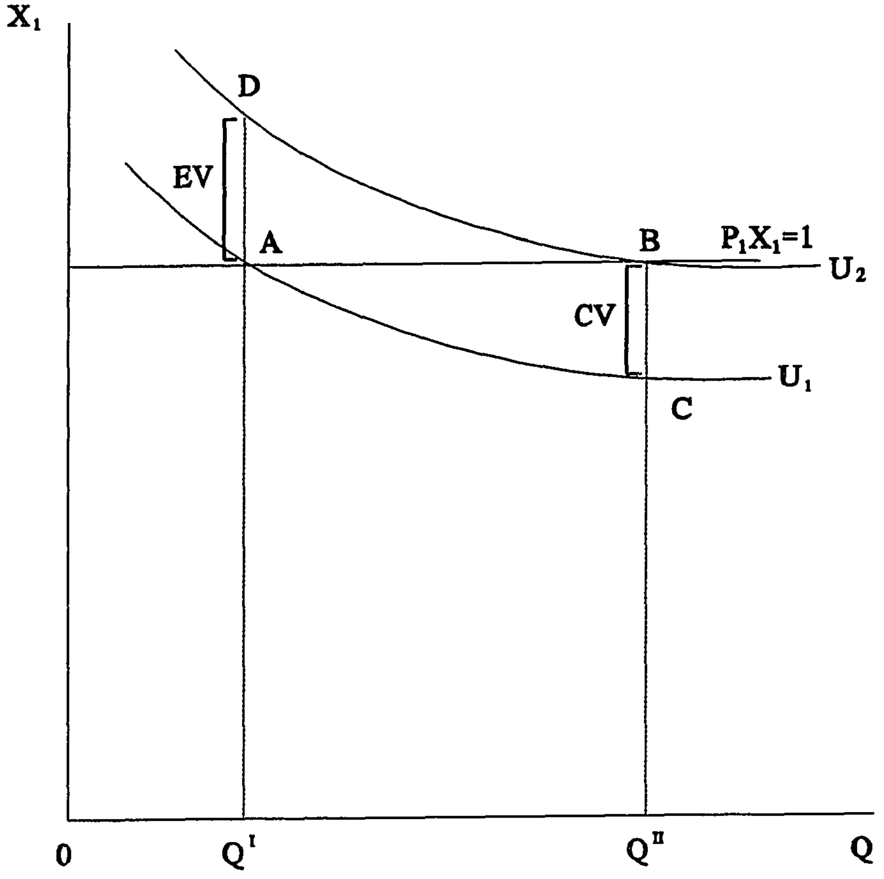

Figure 3.2. CV and EV measures of welfare change

The preference mapping of the individual CV and EV for a change in quantity are shown in Figure 3.2.

As a result of the VBS and related soil conservation activities, it is expected that the level of the environmental good (quality water) will increase to the level Q'' and eventually shift the equilibrium position of the individual from A to B. This is on a higher utility curve U_2. CV measures the quantity of x_1, which must be taken away in order to bring the individual back to the initial indifference curve. The quantity of CV is, in this case, equivalent to B-C. EV measures the change in x_1 given the initial level Q is equivalent to the change in Q. This quantity is shown by the vertical quantity A-D. CV and EV measures also can be obtained from the expenditure function given in equation (3.28). The expenditure function indicates that the utility is a function of private good x, and the environmental good (quality water), where quantity is exogenous to the individual. The partial derivative of the expenditure function with respect to quality water gives the amount expenditure or income must change to hold utility at the specified level as water quality changes. This indicates a marginal WTP or a compensated inverse demand curve. Thus, the CV and EV measures correspond to areas under the inverse demand function compensated to the appropriate utility level.

Having determined these measures of welfare change, there is a practical consideration of whether the welfare measure can be calculated from readily available market data. HCD curve is not directly observable even from the market data and, therefore, the CV, EV, and CS measures for nonmarket data create analytical problems. In principle, it is possible to calculate those values for market data by estimating a complete set of demand functions as a system of equations. If the demand equations satisfy the integrability conditions, the expenditure function can be derived and the HCD function can be computed.

The Benefit Measurement from Nonmarket Data

Some commodities such as timber, corn, rice, or electricity have a market value, while others such as wildlife, recreation, scenic beauty, clean air, and clean water do not have a market value. If the objective is profit or revenue maximization from an activity or production of a nonmarket commodity, such a nonmarket commodity often is assumed to be worth zero because of its zero market value.

An example may help to illustrate the valuation of a market and a nonmarket good. The forester as a revenue maximizer raises and cuts trees that have the highest market value, while, as a citizen, the same person feels that something may be lost in terms of wilderness, scenic beauty, or nature appreciation as a result of his/her decision. However, the choice in this case focuses on the growing and cutting of trees because the value of environmental goods cannot be measured in dollar terms. Thus, these nonmarketed goods are inappropriately valued at zero dollars.

For example, a VBS would reduce chemical runoff and sedimentation from the crop-growing areas. In addition to the water quality, VBS seem have enormous other benefits as spelled out in chapter 2 which cannot be measured in dollars. Generally, the estimation of welfare gains of such commodities is possible through nonmarket means such as surveys, questionnaires, bidding games, and voting procedures. Even if market-related measures of water quality benefits are available, estimations derived through nonmarket techniques are useful as a check on the consistency of the estimation procedures.

Procedures for measuring benefits from the nonmarket data involves revealing people's preferences for the provision of public good. There are few basic approaches to the problem of reevaluation of preferences. One commonly used method is to ask individuals to state their WTP for the environmental commodity (Mitchell and Carson 1989).

There are variety of ways in which questions can be asked of individuals to measure environmental improvement such as water quality. However, all have a common approach, the elicitation of a money value or, in effect, a bid for some specified quantity. Another approach is to ask individuals how much environmental good they would demand at a given price or under given condition of taxation. The price and the tax are determined according to some rule or procedure, based on the expenditure involved in the activity. The individual is asked to behave as if he/she would be in the market for a private good by specifying the quantity demanded conditional on the price. In the case of the tax he/she would reveal his/her WTP a particular amount of tax for the activity. Yet another approach uses voting mechanisms in which two groups compete for votes by specifying alternative programs. The individual may vote either yes or no.

Finally, another commonly used nonmarket benefit evaluation procedure is known as the Travel Cost Method (TCM). Harold Hotelling originated TCM in 1947, proposing that travel cost be used as a surrogate for price in an analysis of trips to a national park. The TCM uses travel costs as prices that reveal the demand curve for a particular recreation site. The idea behind the TCM is that people in population zones surrounding a recreation site will take trips to the site and that the rate of visitation will be a function of the travel costs to the site. The zones further away from the site are expected to have fewer visits, since the price of travel is higher. A statistical relationship is formed that expresses the number of trips per capita as a function of the travel cost to the site and some socioeconomic characteristics of each population zone. This relationship is the aggregate visit locus and provides one point on the demand curve for the site. By assuming that individuals would react to a site entrance fee in the same manner as they would react to an increase in travel costs, the demand curve for a specific recreation site can be developed.

Contingent Valuation Methodology

The Contingent Valuation (CV) is a method of estimating the value of a nonmarket good. The basic assumption is that there is a market for a good such as clean water, wildlife, or clean air and then to ask the individual what he/she would be willing to pay for that good or what he/she would be willing to accept as compensation if this good were lost or unavailable. The dollar value estimated are those values that are contingent upon the existence of a market. CV devices thus involve asking individuals, in a survey or an experimental setting, to reveal their personal valuation of increments or decrements of unpriced goods by using contingent markets. These values for nonmarket goods are then compared to market values to produce more informed choices. Therefore, the ultimate aim of a CV study is to obtain an accurate estimate of benefits of a change in the level of provision of a public good such as quality surface or ground water.

These contingent markets are highly structured to confront respondents with a well-defined situation and to elicit a circumstantial choice contingent upon the occurrence of the posited situation. To achieve this structure and an accurate measure of nonmarket benefits, the survey must simultaneously meet the methodological imperatives of survey research and the requirement of economic theory. CV methodology satisfying above conditions has been used to generate WTP functions for a large and diverse set of consumer goods.[2] This would provide an accurate estimate of the benefits, which could be used for many planning and policy activities in environmental goods.

Theoretical Framework Underlying CV

Modern welfare economics operationalizes a variant of the Pareto Criterion by trying to find ways of placing a dollar

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[2] For an extended discussion of this issue, see Mitchell and Carson (1989).

value on the gains and losses of a provision of a public good. This is based on the two key assumptions. The most basic assumption is that the economic agent (consumer i), when confronted with a possible choice between two or more bundles, must have preference for one over another. The other assumption is that, through his/her actions and choices, the consumer attempts to maximize his/her overall level of satisfaction or utility.

Both of these assumptions have implications for the CV methodology which is unique among benefit measurement techniques for its ability to obtain detailed distributional information. Additionally, CV is consistent with the consumer sovereignty assumption.[3]

The criterion used by welfare economics is to assess a given policy by judging whether a particular policy is effective for Pareto improving. However, in practice, the compensation test of Pareto improvement is not in great use because compensation is rarely paid for losers. For such criterion to be implemented, those who gain from a policy change need to compensate those who lose.

Some economists proposed a new welfare criterion known as Potential Pareto Improvement Criterion or the Potential

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[3] This discussion is based on Mitchell and Carson (1989), Chapter 5.

Compensation Test (Hicks 1939; Kaldor 1939). This criterion has been controversial because, without the actual payment of compensation, it is possible to make a very small group of people much better off while making the vast majority worse off. Nevertheless, the potential compensation test is very popular and widely used among applied economists. CV methodology is providing the information to evaluate benefits by a variety of criteria, including voting and the potential Pareto Improvement Criterion. Application of the potential Pareto Improvement Criterion requires the use of the Hicksian compensating version of consumer surplus.

The CV method provides the only way of directly measuring both WTP and WTA. Depending on which HCS measure a researcher wants to obtain, the elicitation question of the CV survey is phrased in terms of either WTP or WTA. For example, consider the utility function given in equation (3.21). Assume an individual who currently enjoys some specified level Q, of a service and a given Hicksian quantity of all other goods, collectively known as numeraire good, X. His/her level of utility is always dependent on the numeraire good (for convenience it is called income) and the quantity of the particular service Q where

$$U = U(Q,X) \tag{3.31}$$

The situation can be explained clearly using the Figure 3.3. The origin Q^0 indicates an individual's initial level of welfare. On the right side of the origin, towards Q^+, the level of the provision of Q to the individual increases while to the left of Q^0, it decreases. Movement up the vertical axis denotes that income decreases; while a movement down indicates an increase in income. The total value (TV) curve or Bradford Bid curve, is positively sloped, given that the service is a commodity and the individual is not satiated in the range under consideration. The horizontal axis of TV represents quantity in increasing amounts, and the vertical axis represents income in decreasing amounts. If it is possible to define the quantity of the service in undimensional, cardinal terms, the assumption of diminishing rates of commodity substitution is sufficient to ensure the curvature shown. Alternatively, if the quantity of the service is multidimensional, or if it cannot be defined accurately in cardinal terms, no *a priori* assumption can be made concerning the curvature of the TV curve (Bradford 1970). The empirical estimate of a TV curve provides the total value to an individual of an environmental good or service such as an increment or decrement. This can be estimated in a form

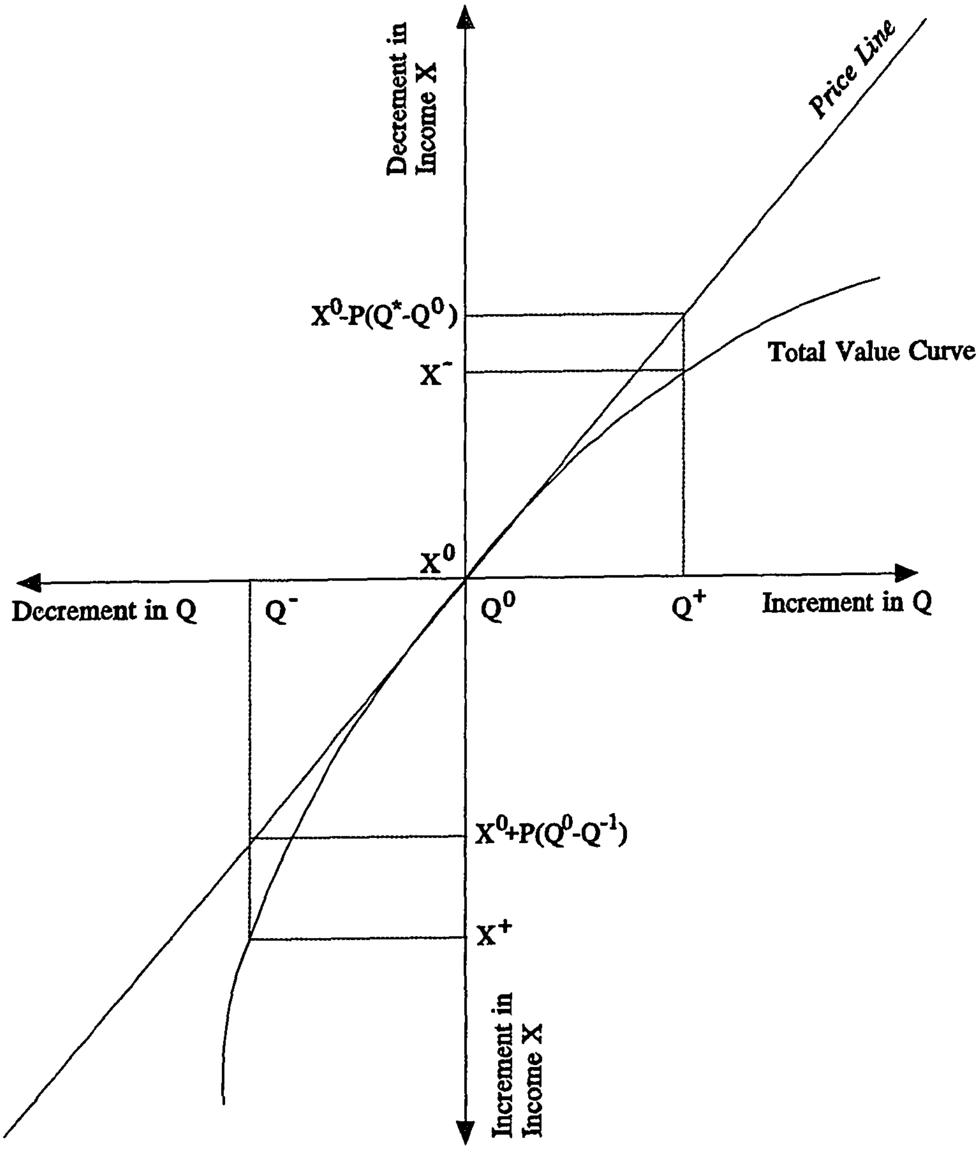

Figure 3.3. The total value curve for changes in Q

entirely consistent with the potential Pareto Improvement Criterion. To determine any proposed change in output, individual total values may be aggregated across the relevant population.

The TV curve is an indifference curve, passing through the individual's initial state, that is,

$$U(Q,X) = U(Q^-,X^+) = U(Q^+,X^-) \qquad (3.32)$$

As noted in Figure 3.3, WTP is the total value to the individual of an increment from Q^0 to Q^+ and WTA is the total value to the individual of a decrement from Q^0 to Q^-. Thus, equation (3.32) becomes

$$U(Q^0,X^0) = U(Q^-,X^0+WTA) = U(Q^+,X^0-WTP) \qquad (3.33)$$

If quality improvement from Q^0 to Q^+ is a one-unit increment in Q, WTP is equal to the buyer's best offer for that increment. Similarly, with a unit of quality decrement from Q^0 to Q^-, WTA is equal to the seller's reservation price for that decrement. If an increment would cost more than an individual's WTP and a decrement would net the individual less than his/her WTA, he/she probably would refrain any trade in Q and remain at his/her initial situation.

The appropriate measure to evaluate the benefit cost of water quality improvement in the Bear Creek watershed is the CS defined by the Hicksian measures. The Bear Creek project was not proposed primarily for the purpose of redistribution. Therefore, the potential Pareto Improvement should be the proper criterion for water quality improvement using Hicksian compensating measures. Those compensating measures, by using initial welfare level as the reference level, measures the impact of changes as if the individual had a right to his/her initial level of welfare. Equivalent measure uses the subsequent welfare level as the reference level and treats the individual as if he/she had only a right to his/her subsequent level of welfare. Hicksian compensating measures are consistent with the potential Pareto Improvement Criterion, while equivalent measures are not.

During the last two decades, considerable research efforts in the economics of public goods have been devoted to problems of estimating demands for public goods. A major part of this research effort has been devoted to finding a mechanism for direct questioning of consumers concerning misrepresenting preferences for public goods.

Variations in CV Elicitation Designs

CV methodologies simulate a market for a nonmarket good. In this process, we estimate the respondent's consumer surplus for the environmental good, and the maximum amount the nonmarket good is worth to the respondent. The best way to do this would be to ask individuals their willingness to pay for the good and record the answer. This is called an open-ended CV format because the respondent is not given a price to accept or reject. Respondents often find it difficult to assign a value spontaneously without some form of assistance. As a result, many open-ended CV formats tend to produce an unacceptably large number of nonresponses or protest zero responses to the WTP questions (Desvousgas et al. 1983).

There are a few widely used elicitation techniques that attempt to overcome the weaknesses of general CV formats. Many CV researchers have accepted these techniques as capable of reducing nonresponses and making it easier for respondents to successfully complete the valuation process. The commonly used elicitation methods are (1) the bidding game, (2) the payment card, (3) the discrete choice (take it or leave it offer), and (4) the discrete choice with follow-up approaches.

The oldest and the most widely used CV method until recently has been the bidding game (Davis 1964). The process is identical to normal auctions and, therefore, is likely to be familiar to respondents. This is normally modeled on a real-life situation in which individuals are asked to state a price for the environmental nonmarket good. This bidding game format is best adapted to personal interview surveys, but it also may be used in telephone surveys. The use of this format in mail surveys, however, is very limited. The interviewer iteratively changed the stated amount of money to be paid or received until the highest amount the respondent is WTP, or the lowest amount the respondent is WTA, is precisely identified. Thus, the identified amount is an estimate of a point on the total value curve. According to Cummings et al. (1986), the bidding process likely will capture the highest price consumers are WTP and thereby measures the full consumer surplus. Also, as Hoehn and Randall (1983) stated, the process of iteration used in this CV bidding process will enable the respondent to more fully consider the value of the environmental nonmarket good. Many researchers have demonstrated that starting-point bias occurs when the bidding game format is used (Cummings et al. 1986; Mitchell and Carson 1985; Roberts et al. 1985; Boyle et al. 1985; Welle 1985).

The payment card method was first developed by Mitchell and Carson (1981 and 1984) as an alternative to the bidding game. This method maintains the properties of the direct question approach while increasing the response rate to WTP question by providing respondents with a visual aid. This is a more sophisticated direct questioning technique, which specifies the increment or decrement in value for the nonmarket good to be provided in quantitative terms. Furthermore, this method provides substantial details about the institutional structure of the hypothetical market.

The question may be a open-ended or closed-ended format. The open-ended format provides an exact dollar amount for WTP by the respondent, which is a point on the TV curve. The closed-ended format provides a yes or no answer to a question specifying both the precise amount of a nonmarket good to be gained or lost and the precise amount of money to be paid or received. The payment card procedure evades the need to provide a single starting point and offers the respondents more of a context for his/her bid than is provided by the direct question method.

The adaptability of payment cards in mail surveys is very limited and the method seems to pose less of an anchoring problem than the bidding game or direct questioning. This method is potentially vulnerable to biases associated with the ranges used on the cards and the location of the bench mark (Mitchell and Carson 1989).

The third CV elicitation method is the discrete choice (also known as dichotomous choice, take-it-or-leave-it, referendum, or closed-ended), which was developed by Bishop and Heberlein (1979). This approach uses a large number of predetermined prices chosen to bracket expected maximum WTP amounts of most respondents for the nonmarket good.

Because respondents find it very difficult to identify precisely their true point value of access to some environmental good, open-ended valuation questions can be unreliable or can discourage response. In contrast, most consumers are familiar with being confronted by a posted price for a good and the need to make a decision to purchase at that price. This is the strategy behind the discrete choice CV questions.

The advantage of the discrete choice method over other methods is that it simplifies the respondent's task in a fashion similar to the bidding game without having the iterative properties. The respondent, just like any other consumer, has only to make a judgment about a given price. Therefore the method may be especially suitable for mail surveys.

The main obstacle of this method, relative to other elicitation methods, is that many more observations are needed for the same level of statistical precision in sample WTP estimates because only a discrete indicator of maximum WTP is obtained instead of the actual maximum WTP amounts.

The other problem is that analysis is dependent on some assumptions about how to parametrically specify either the valuation function or the indirect utility function to obtain the mean WTP. Bishop and Heberlein (1979) noted that a logistic or probit regression curve could be fitted to the percentages of respondent's WTP each of the randomly assigned prices. Integrating the area below the logistic curve, would provide equivalent measure to the mean WTP. It also is possible to obtain mean WTP directly from the parameters of a probit equation.

The fourth widely used elicitation process is the discrete choice with a follow-up approach. Using this method Carson and Mitchell (1986) asked a question requiring a yes or no answer regarding the respondent willingness to pay a specified price. If the respondent says yes, another question is asked using a higher price randomly chosen from a prespecified list. If the respondent says no, a lower price is used in the follow-up question. Although this procedure offers potential for considerable gains in efficiency, the inherent problems of discrete choice still remain. Further, the follow-up questions used in this method are similar to the iterative procedures of the bidding game. The main disadvantage is that this method is not suitable for mail surveys because of the follow-up approach.

An extension of this procedure, known as the modified dichotomous choice method, was used to measure the existence value of wildlife by Stevens et al. (1991). In this approach, the respondent was confronted with the specified amount of money, he or she would contribute toward continued existence of the resource. The amount of money was randomly selected within fixed intervals over a range of $5 to $150. Also, all respondents were given an opportunity to bid an amount less or greater than the specified amount of money. Responses, therefore, could be viewed as originating from either an open-ended or a closed-ended dichotomous choice bidding format. Unlike the discrete choice follow-up approach, this method can be used in mail surveys.

Dichotomous Choice CV Model: Methodology

A modified dichotomous choice (DC) method was used for the evaluation of benefits associated with the Bear Creek water resource protection. Among the alternative CV question formats, DC is emerging as the preferred method because it can be used in a mail survey, it successfully elicits individual participation, and is free of starting-point bias.

Open-Ended DC Format

The open-ended format allowed the respondent to specify a monetary figure for water protection by VBS, other management practices, and the Story County Ground Water Protection Plan. Values provided by respondents were direct estimations of WTP and the points on TV curve. By asking the amounts respondents would pay, points on the individual's bid curve (Bradford 1970) or TV curve (Brookshire et al. 1980) can be obtained. The dependent variable is the respondent's annual average WTP for water quality improvement in surface and ground water. The independent variables of the bid curve are specified as levels of gross income, present and expected level of water quality, education, family size and sex. The distance to Bear Creek from the land on which they live or cultivate is used as an independent variable only in the surface water quality bid curve. The open-ended CV model was specified as

$$WTP = f(Q^n, Q^e, X, E, F, S, D) \tag{3.34}$$

where

Q = the level of provision of the service, Q^n is the present water quality, Q^e is the expected water quality

X = gross income level

E = level of education

F = family size

S = gender (male/female)

D = distance to the Bear Creek

WTP = Hicksian equivalent measure of WTP.

The equation provides the relationship between the WTP value and each independent variable. Because there was no information *a priori* about the choice of a functional form, the bid curve (3.34) can be estimated using ordinary least square (OLS) procedures. To find the inverse HDC, it is necessary to differentiate the bid curve. This demand curve in unique to the reference welfare level.

Closed-Ended DC Format

Closed-ended CV surveys also known as referendum surveys have recently become very popular as a technique for eliciting the value of water resources. The procedure involves first establishing the attributes of the water resources and then asking the respondents about their WTP for a single specific sum for keeping water resources clean. As pointed out earlier, the questioning strategy is attractive because it generates a scenario similar to day-to-day market transactions. A pre-tested hypothetical value would be tested to determine whether the respondents would agree to take it or leave it at that price. In this format the respondents were asked to give one of the two responses, yes or no, to the following question:[4]

Assume that the current water quality level that you indicated in Q #10 is to be changed to your acceptable water quality level given in Q #12,

a) Would you be willing to pay $ X each month for this change as long as you live in this area?

Yes No (circle your answer)

b) What is the maximum that you would be willing to pay each month?

$________ Month

The relationship between the other variables and the WTP for water quality can be observed in the sample survey responses to part (a) of the above question. Independent variables, such as income, existing level of water quality, etc., are continuous. The dependent variable is the WTP status, which is an attribute, a qualitative variable, or a discrete variable. For a single attribute, this dependent variable Y is a scaler, which can take only two values, and is defined as

Y_i = 1, if respondent says yes to part (a)

Y_i = 0, otherwise.

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[4] See Appendix, Survey Questionnaire.

The appropriate model to analyze this type of response data is a binary response model in which the dependent variable takes one of the two values (Seller et al. 1985).

A regression line could be fitted to these data by using any econometric technique, but the underlying model make no sense of this exercise. One may, of course, still define a linear relationship and make it hold identically by introducing an additive disturbance term ϵ_i, as in

$$Y_i = \alpha+\beta X_i+\epsilon_i \qquad (3.35)$$

It is necessary to assign complex properties to the ϵ_i to restrict the Y_i to the observed values 0 and 1. Thus, ϵ_i cannot have the simple properties that are the main appeal of the regression model. The solution to the problem is to regard Y_i as a discrete random variable and to make the probability of $Y_i = 1$ not the value of Y_i itself. This leads to a probability model that specifies the probability of a certain response as a function of the activator.

$$P_i = Pr(Y_i=1) = P(X_i,\theta) \qquad (3.36)$$

and

$$Q_i = \Pr(Y_i=0) = 1-P(X_i,\theta) = Q(X_i,\theta) \qquad (3.37)$$

where,

Pr( ) = the probability of the event

P( ) = probability as a function of certain argument

Q( ) = compliment of P( )

θ = vector of parameters that govern its behavior.

The regression equation, therefore, is specified as

$$P(X) = \alpha + \beta X \qquad (3.38)$$

which is the Linear Probability Model (LPM), and the estimation of α, and β can be made by the linear regression model.

Suppose that we have $n_i>1$ observations on the discrete choice behavior of the ith individual, where $i=1,\ldots,N$. Each individual under consideration is characterized by a $(K\times1)$ vector x_i containing values of explanatory variables. We observe n_i trials corresponding to each vector x_i. Let y_i equal the number of occurrences of one of the alternatives and, therefore, proportions of the occurrences of a particular event Z in n_i trials is

$$P_i = \acute{X}_i\beta + \epsilon_i \quad i = 1,\ldots,M \tag{3.39}$$

Thus the full set of observations can be written in matrix form, as

$$\mathbf{P} = \mathbf{XB} + \mathbf{E} \tag{3.40}$$

If the sample proportions p_i are related to the true population P_i by,

$$P_i = \mathbf{P}_i + \epsilon_i \quad i = 1,\ldots,M \tag{3.41}$$

where P_i is the probability of that particular event Z, given the values x_i, then the error term ϵ_i has zero mean and variance $P_i(1-P_i)/n_i$. The covariance matrix of ϵ is then,

$$\Omega = E(e\acute{e}) = \begin{vmatrix} \frac{P_1(1-P_1)}{n_i} & 0,\ldots & 0 \\ 0 & \frac{P_2(1-P_2)}{n_2},\ldots & 0 \\ 0 & 0 & ,\ldots\frac{P_M(1-P_M)}{n_M} \end{vmatrix} \qquad (3.42)$$

The appropriate estimator for B in equation (3.40) is

$$B = (\acute{X}\,\Omega^{-1}\,X)\;\acute{X}\,\Omega^{-1}\,P \qquad (3.43)$$

which is the generalized least square estimator (GLE). The true population P_i is generally unknown but is consistently estimated by p_i. Thus the GLE provides the values for estimated Ω, which is the consistent estimator obtained by replacing P_i in equation (3.42) by p_i. The estimated B is asymptotically normally distributed, and a consistent estimator of the covariance matrix, which may be used as a basis for hypothesis testing. The predictor $p_i = x_i'\beta^*$ is interpreted as a predicted probability.

However, the main drawback of this model is that nothing ensures that the estimated p_i will fall in the unit interval. Probabilities are, of course, restricted to the interval from 0 to 1. As a result, the LPM imposes harsh and quite possibly arbitrary constraints on the values the regression coefficients may assume. As long as the linear assumption is maintained, least squares estimation with a correction for heteroscedasticity and some care in interpretation in small samples is viable.

There are a variety of reasons the assumption that a probability model is linear in the independent variables is frequently unrealistic. If the model is incorrectly specified as linear, the statistical properties derived under the linear assumption generally will not hold. The parameters being estimated may not even be relevant. The only apparent solution to this problem is to specify a nonlinear probability model in place of the LPM.

This approach, consider the larger value of the index that will occur, as the greater probability of the event. It is assumed that a monotonic relationship exists between the value of index and the probability of the event occurring. Therefore, the true probability function would have the characteristic shape of a cumulative distribution function (CDF). The most commonly used CDFs are the normal and logistic. In practice, the normal density leads to the Probit model while the logistic density yields the Logit model. For a variety of reasons, however, the logistic and normal curve specifications are used frequently as alternatives to the linear specification of the probability model.

Estimation of Probit and Logit Models

The basic conception of the nonlinear models for estimation with a binary dependent variable has been covered in the previous section. This section covers estimation of parameters for the Probit and Logit model and the problems associated with the estimation procedures. The dependent random variable Y in this model is assumed to be binary, taking on two values, say 0 and 1. The outcomes on the dependent variable are assumed to be mutually exclusive and exhaustive. Y generally, is dependent upon K exogenous variables, which accounts for the variation of P. Thus, the relationship can be expressed as $P=P(Y=1|X_1,...,X_k)$, where X denotes the set of K independent variables. This assumption is similar to the assumption of thc standard regression model. In OLS regression, Y and X are linearly related, but in Probit and Logit cases the relationship between Y and X are quite different, which is shown in the next section. As in OLS regression, the data are generated from a random sample of size N with a sample point denoted by $i=1,...,N$. Thus, the observations on Y are statistically independent of each other ruling out serial correlation. As for the linearity assumption in the OLS, this method assumes that there be no exact linear dependence among the X_{ik}s. Furthermore, it implies that $N>K$ and that each X_k must have some variation across observations. Thus, there are no two or more X_ks, which are perfectly correlated. However, as with OLS, Probit and Logit suffer the problem of multicollinearity if near though not exact linear dependencies exists.

The Probit Model

The normal density function generally leads to the Probit model and assumes the general form of a CDF. Consider the relationship between the unobservable index variables.

$$T_i = \acute{X}_i \beta \tag{3.44}$$

In the equation (3.44), β is considered to be linear such that the larger the value of P_i the greater the probability of the event E occurring. The monotonic relationship between T_i and $Pr\{E|T_i\}$ must be assumed since the probability must fall between 0 and 1. The Probit model further depends on the assumption that all individuals allocate equal weights to X_i, the explanatory variable. Thus, an individual's β vector is constant. Some will choose event E and others will not because of personal preferences. This choice between E and not E depends on the individual values of T_i and some threshold value T_*, so that if $T_i \geq T_*$, then E occurs. The individual valuation of T_* depends on many individual factors. This can be expressed as follows using Central Limit Theorem and the normality assumption.

$$P_i = Pr(E|T_i) = Pr(T_* \le T_i) = F(T_i) = F(X_i\beta)$$
$$= \int_{-\infty}^{T_i} \frac{1}{\sqrt{2\pi}} \exp\left(\frac{-t^2}{2}\right) dt \tag{3.45}$$

We have seen from the equation (3.41), that

$$F^{-1}(p_i) = F^{-1}(P_i + e_i) \tag{3.46}$$

F^{-1} denotes inverse of the normal CDF, which is equivalent to the T_i. The RHS of the above equation can be approximated using a Taylor series expansion of P_i. Thus we have

$$F^{-1}(P_i) = F^{-1}(P_i) + \frac{e_i}{f[F^{-1}(P_i)]} \tag{3.47}$$

where f( ) is the value of the standard normal density evaluated at its argument. Therefore, we have

$$Z = F^{-1}(P_i) = \acute{X}_i\beta + \mu_i \quad i=1,\ldots,M$$
$$\beta^* = (\acute{X}\,\phi^{-1}\,X)^{-1}\,\acute{X}\,\phi^{-1}\,Z \tag{3.48}$$

which is the observed Probit estimator, and the value μ_i is such that,

$$E(\mu_i) = 0, \quad Var(\mu_i) = \frac{P_i(1-P_i)}{n_i[f(F^{-1}(P_i))]^2} \tag{3.49}$$

<u>The Logit Model</u>

The Logit model is based on the logistic CDF and is frequently used as an alternative to the Probit model. The logistic CDF given below closely approximates that of a normal random variable and has some convenient properties.

$$P_i = Pr(I_* \leq X_i'\beta) = F(X_i'\beta) = \frac{1}{[1+\exp(-X_i'\beta)]} \tag{3.50}$$

Using the Taylor series expansion and the probability expansion, the probability function can be rewritten as

$$L = \ln(\frac{p_i}{1-p_i}) = \ln(\frac{P_i}{1-P_i}) + \frac{e_i}{P_i(1-P_i)}$$
$$= X_i'\beta + \mu_i, \tag{3.51}$$
$$\textit{since} \quad \ln(\frac{P_i}{1-P_i}) = X_i'\beta$$

Probit and Logit parameters can be estimated using the Maximum Likelihood Estimation (MLE) method. MLE is a visible alternative to OLS in many situations. Generally, exact (small sample) properties of the MLE (unbiasedness, efficiency, normality) cannot be established. The MLE typically exhibits the asymptotic (large sample) properties of unbiasedness, efficiency, and normality. A minor drawback of MLE on Probit and Logit is that the likelihood estimation on those models is nonlinear in the parameters and cannot be estimated. The result, is that algebraic solutions are not obtainable. Instead, approximation by standard iterative algorithms are widely used.

Integration of the Area under Logit Curve

The fourth method of estimating WTP values is to integrate the area under the Logit model given in Figure 3.4. The shaded area of the graph represents the expected WTP for water quality protection, which is the Hicksian equivalent measure of welfare change. Thus, we have

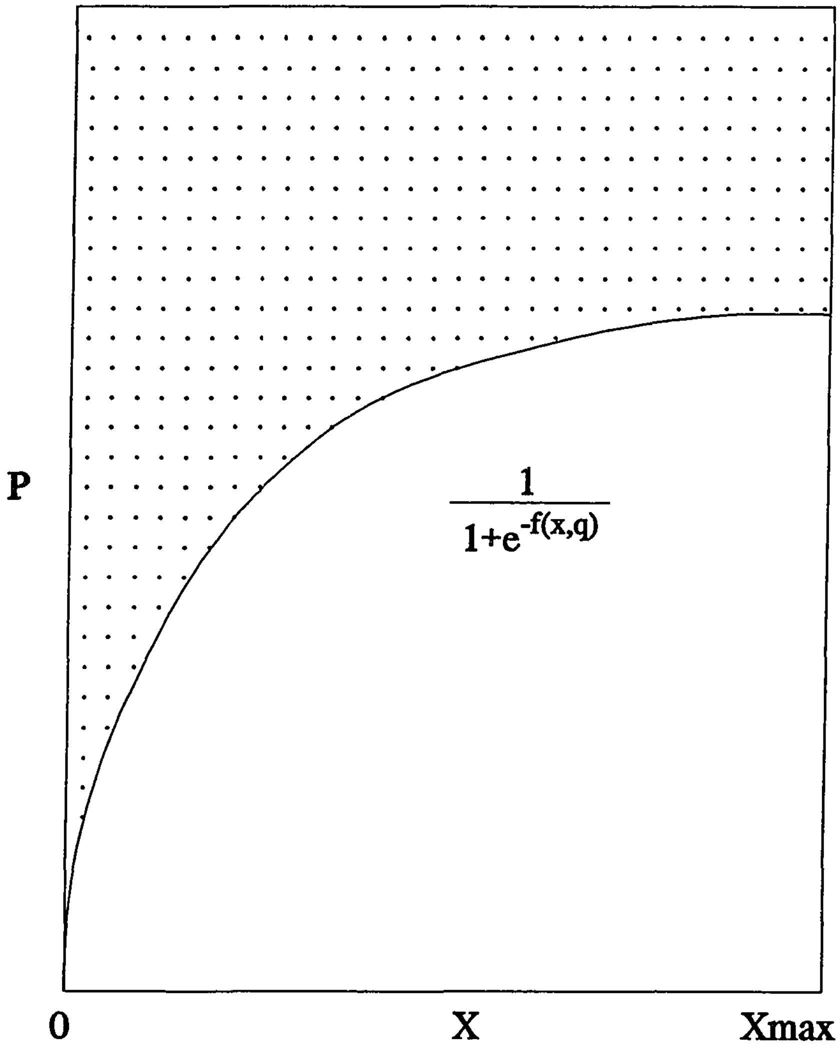

Figure 3.4. The Logit Model

$$E(WTP) = \int_0^{X_{max}} (1-F(X))\,dx \tag{3.52}$$

where,

F(X) is the cumulative distribution corresponding to f(x), which is the probability distribution for responding yes to WTP price X. Then 1-F(X) is the probability of responding no to the price X, which is equivalent to P(X).

The expected WTP is equivalent to,

$$E(WTP) = [(1-F(X))X]_0^{X_{max}} - \int_0^{X_{max}} (1-F(X))\,dx \tag{3.53}$$

Integrating the above by parts gives

$$\begin{aligned} E(WTP) &= X_{max} - \int_0^{X_{max}} P(X)\,dx \\ &= X_{max} - \int_0^{X_{max}} \frac{1}{1+e^{-(\ln\alpha+\beta\ln x)}}\,dx \end{aligned}$$

which implies that the mean WTP is represented by the shaded area in Figure 3.4. X_{max} in the Figure 3.4 corresponds to the highest closed-ended dollar offer used in the valuation exercise. However, variable q in the equation (3.53), which is the quantity of water used, has been implicitly fixed at the mean value. Allowing q to be a variable,

$$E(WTP) = X_{max} - \int_0^{X_{max}} \frac{1}{1+e^{-(\ln\alpha+\beta\ln x+\delta\ln q)}}dx \tag{3.54}$$

The equation (3.54) also can be expressed as

$$E(WTP) = X_{max} - \int_0^{X_{max}} \frac{1}{1+\alpha^{-1}x^{-\beta}q^{-\delta}}dx$$

The expression of equation (3.52) or (3.53) is the Hicksian equivalent surplus measure of welfare change. This equivalent surplus is defined as the consumer's WTP to avoid the loss of a commodity, which, if paid, would place the consumer at the subsequent welfare level.

A total value function given in the Logit model (3.50) may be derived by evaluating equation (3.54) at varying levels of q_i. The first derivative of this total value function is a marginal value curve or an inverse Hicksian demand curve (Bradford 1979).

$$\frac{dE(WTP)}{dq} = \frac{-\delta}{\alpha}\int_0^{X_{max}} \frac{1}{(1+\alpha^{-1}x^{-\beta}q^{-\delta})^2 x^{\beta} q^{\delta+1})} dx \tag{3.55}$$

The estimated coefficient for α is expected to be positive, while the coefficient for β is expected to be positive and δ to be negative. This indicates that the probability of a no response is expected to increase with the magnitude of the suggested WTP price and decrease as q increases. This derivative must, therefore, be nonnegative.

The sign of the second derivative with respect to q indicates the direction of the slope of the demand curve.

$$\frac{d^2E(WTP)}{dq^2} = -\frac{\delta}{\alpha}\int_0^{X_{max}} \frac{-(\delta+1)}{(1+\delta^{-1}x^{-\beta}q^{-\delta})x^{\beta}q^{\delta+2}} + \frac{2\frac{\delta}{\alpha}}{(1+\alpha^{-1}x^{-}\beta q^{\delta})^3 \; x^{2\beta} \; q^{2(\delta+1)}} \, dx \tag{3.56}$$

This derivative is negative, indicating that the Hicksian demand curve (HDC) is downward sloping. This condition is satisfying if the coefficient δ satisfies the condition $-1 < \delta < 0$. This indicates that the probability of responding no to a price should decrease as the quantity of the good consumed increases. When those conditions are satisfied, that the

Hicksian demand curve is positive and downward sloping is guaranteed. These results can influence the choice of the functional form.

Survey Methodology and Biases

The use of the CV approach to valuing public goods has grown dramatically in the last 25 years with more sophisticated survey designs being the major improvement. The valuation of environmental quality change has been emphasized in CV methodologies in recent years. In the case of water resources, a water quality ladder[5] has been used to indicate the various levels of water quality as a common yardstick. For example, the water quality ladder may contain such steps as boatable, fishable, swimmable, and drinkable (Mitchell and Carson 1989). This allows the investigator to ask how much one would be willing to pay for an improvement from one level to another. Various techniques are used to measure the change of a provision of a good, and those estimated values are quite sensitive to the technique employed and the method of analysis.

The CV approach suffers from a variety of theoretical and practical difficulties. Those who pioneered the

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[5] For an example of water quality ladder, see Bear Creek survey questionnaire in Appendix, page 184.

development of CV technique in the 1970s were sensitive to the possibility that systematic error might affect their results. There are several potential sources of bias given the nature of the CV technique and the survey instrument. Among the more important biases are hypothetical, strategic, starting point, information, sample-related, and the vehicle biases (Edward and Anderson 1987).

According to the standard economic assumptions, the strategic behavior in CV will be a function of the respondents' perceived payment obligation and the respondents' expectations about provision of a public goods. Because of strategic behavior, respondents tend to give a WTP amount that differs from their true WTP amounts in an attempt to influence the provision of the public goods. Samuelson (1954), in his original article on the provision of public goods, maintained that individuals could not be expected to reveal their true WTP for strategic reasons. There are some tests available to overcome strategic behavior.

CV approaches that use the iterative bidding game techniques suffer from starting-point bias in that the respondent may anchor to an initial point in a bidding experiment. An iterative bidding procedure begins with some arbitrary initial value. If the respondent agrees to that value, the bid value is increased until negative response is reached. If the initial value is a negative one, the bid value is revised downward until reaching an acceptable response. The final bid value is equivalent to the Hicksian compensating or equivalent surplus. In general, starting-point bias occurs because the value selected to initiate the bidding game has an appreciable impact on observed final bids. This impact could take place in two ways. First, if the starting point is far away from the true value, the procedure terminates before the true bid is reached. The starting value also conveys information to the respondent about expected or reasonable bids and, thereby, influences the final bid outcome. The information transfer effect is related directly to the initial or starting bid amount.

When respondents are asked how much in increased taxes they would be willing to pay versus how much they would pay via other methods, the response may be significantly different. This difference in WTP, dependent on the method of payment, is known as vehicle bias. Generally, the vehicles used in CV are utility bills, entrance fees, taxes, user fees, and higher prices. At times, respondents do not understand the scenario in the way intended by researchers because of the gap between plausibility and understandability. Therefore, the payment vehicle is either misperceived or is itself valued in a way unintended by the researchers.

Respondents also may change their values depending on the amount of information they are given about the environmental commodity or situation. For example, if information on present tax expenditures is given, the respondent may provide a different value than he/she would where he/she not informed about the tax expenditure. This phenomenon is termed information bias. An information overload effect also can occur whereby respondents ignore important information and focus on and possibly misinterpret unimportant information.

The definition of the population, decision about the sampling frame, and attempt to obtain valid WTP responses and nonresponses are some of the decisions. Although the theoretical and practical problems associated with sampling errors should not be taken lightly, nonresponse is probably a much greater source of bias in survey research (Cochran 1963). Whether or not sampling errors exist, systematic differences between respondents and nonrespondents usually will invalidate inferences based solely on data from respondents. This could be evaluated by subsampling at least 10 percent of the nonrespondents when testing for sampling bias.

Sample selection bias concerns differences in behavioral parameters that weight the determinants of behavior. This occurs when the probability of obtaining a valid WTP response among sample elements is related to the respondent's value for the good. Mail surveys generally are prone to errors of sample selection bias because of the potential for nonrespondents to be consciously self-selected. Edwards and Anderson (1987) demonstrated various sources that could influence the sample selection bias and two parametric procedures that test for their occurrence. They also provide an illustration of the magnitude of nonresponse bias in estimates of aggregate benefits. Mitchell and Carson (1989) demonstrated various sources of biases and their magnitude along with methodological problems and possible treatments.

CHAPTER 4 ESTIMATING THE BENEFITS OF PROTECTING WATER QUALITY

The objective of this study is to measure environmental protection benefits of protecting water resources from agricultural pollution using the framework of welfare economics. The study was carried out in the Bear Creek watershed, located in central Iowa. The location was selected due to the existence of a research VBS in the same watershed. There are strong theoretical grounds to use survey-approach based CV methodology for this purpose. The mail-out survey was used to learn people's perception about the surface and ground water quality, the effectiveness of VBS and other conservation measures to control agricultural pollution, and to obtain the individual's WTP measures for such activities.

Bear Creek (BC) Survey Design and Methods

In order to carry out the CV study, a sample survey was designed and applied in the Bear Creek watershed area, located in Story and Hamilton counties, central Iowa. The 7160 ha Bear Creek watershed is located in the heart of predominantly agricultural land. This north-south watershed is drained by Bear Creek, which flows for 34.8 km before it unites with the Skunk River. Bear Creek has 27.8 km of small tributaries, which drain undulating to level topography. Lands presently occupied with agricultural crops were originally covered with prairie vegetation except for riparian forests along the lower end of the creek. Most of the cultivated agricultural crops within the BC watershed are corn and soybeans. There are no major recreational areas in the watershed area, though some areas are suitable for wildlife and nature appreciation. Soils in the watershed which are formed in glacial till or from local alluvium from till, range from well-drained to poorly drained.

Sampling Design

The universe of the study was created from two major public sources of information. One was a listing of land owner farmers in Story and Hamilton counties available at the respective county auditor's office. Platt maps show the location of farms with reference numbers that can be used to obtain data such as ownership, address of the owner, and the acreage. Data related to each farm are accessible through a computer data base, which was used for sorting all data for each farm delimited by the watershed. Absentee land owners were identified using this information.

The other public source of information was the Roland city telephone directory. The sampling frame consists of three different study groups: land owners and farmers who live in the Bear Creek watershed, absentee landowners, and the citizens and business owners of Roland. Owners of the farmlands are basically those farmers, reside in the Bear Creek watershed and currently engage in full or part-time farming activities. Absentee land owners have been defined as land owners who live outside Story or Hamilton counties and rented out their land for cultivation. Non-farmers are those who live in the town of Roland engaging nonfarm activities.

The total population of the study area includes 874 households comprising 292 farmers, 42 absentee land owners, and 546 citizens of Roland. A simple procedure was adopted to draw a sample by using a systematic sample method. From the total population of 874, sample of 153 farmers, and 150 citizens was drawn systematically. Survey research suggests that the response from absentee land owners generally is poor and, given that the population of absentee land owners is very small, all 46 were sampled. Thus, the total sample selection across all three groups totalled 349 from the total population of 846.

A town meeting was held to provide information and educate the people of the area about the project and survey. In addition, newspaper articles, and other published materials were used to provide sufficient information about the study.

<u>**Questionnaire Design**</u>

The questionnaire, presented in Appendix, was designed to be easily understood and filled out without external consultation. Many parts were self-explanatory but, where it was necessary, clear explanations were provided. Opportunity cost, and embarrassment were reduced by keeping the questionnaire brief, by writing clearly and using easy-to-follow instructions. Trust was established by identifying ourselves with Iowa State University, the Leopold Center for Sustainable Agriculture, and the some of the leaders of the area.

There were eight sections to the questionnaire, each of which began with a transition statement explaining why the remaining questions were being asked. The cover page consisted of a map showing the Bear Creek watershed, all townships of both counties, and major roads. The purpose of the map was to allow respondents to locate their land. It also allowed for cross checking addresses of respondents and their location. Moreover, it was a reminder that they live in the watershed and helped emphasize the concept of social responsibility to keep the water resources clean.

Section one of the questionnaire surveyed the location of the land, the houses, and the present use of Bear Creek. The beginning of section two contained a question that verified the farmer's status. For example, if the respondent was a full-time or part-time farmer, the rest of the section about farming activities needed to be completed; non-farmer respondents moved on to section three. Responent's attitude on potential sources of water pollution are revealed in this section.

Section four included questions about surface water quality and WTP values. Water quality ladders have been used in other studies (Mitchell and Carson 1989) to indicate current water quality and the expected water quality in terms of a scale of 0 to 10. The 0 level indicates worst possible water quality, which is unfit for human, wildlife, livestock, and crops uses, whereas level 10 is the best possible water quality fit for human drinking.

Section five dealt with the ground water quality of the Bear Creek watershed. This section also revealed the sources of drinking water and the WTP to keep ground water sources clean. The same water quality ladder was used for this purpose.

Section six dealt with soil conservation and stream zone practices. Respondents were asked how they felt about the VBS and other soil conservation practices. Further, they were questioned about their attitude on VBS and other conservation practices in terms of protecting water resources. Willingness to Accept (WTA) values were asked for the voluntary establishment of the VBS from the full-time and part-time farmers only, given that they would have to adjust their farming practices and incur real costs to establish a riparian VBS. Social action plans were discussed in the next section, including the concept of a Creek Team Program (CTP), which is a voluntary citizens group established to adopt Bear Creek and maintain quality water in it. The final section pertained to respondents' socioeconomic and demographic variables, which were collected and used later as independent variables in the WTP function.

The questionnaire was pre-tested with a target group and modified before it was sent to the respondents. Two group meetings and the sample pre-test were useful to disseminate the idea about VBS in general and the specific objectives of the sample survey.

Execution of the Survey

The first communication with the respondents was a personalized letter indicating the objectives of the survey and the importance of their participation for the success of the study. Respondents also were informed in advance that they would receive a questionnaire to complete and return in the postage paid envelope provided. A week later, the questionnaire was mailed with a personalized cover letter, an illustration of a model VBS, and a postage paid envelope. Both letters identified the university departments involved, the funding institution, and the topics addressed, and explained how their name was selected, why their participation was important, and their guaranteed anonymity. Care was taken to keep the tone of the letter neutral.

The first follow-up letter was mailed to those who did not respond within the first 14 days. Those who had returned a questionnaire were thanked and the others were urged to complete and return the survey. A week later, a post card reminder was mailed to all nonrespondents. A month after the first mailing, another cover letter, questionnaire, drawing of a VBS, and the postage paid envelope were mailed to nonrespondents. This cover letter placed more emphasis on the importance of their response and stated that would take only 20 minutes to complete the survey. All letters were personalized by typing each person's name and address and by signing each letter individually.

Survey Results

The response rate to the survey was 40 percent, which is fair for a mail survey. The correct way to calculate the response rate for a mail survey is to divide the number of questionnaires returned by the number in the original sample (Dillman 1978). Out of 345 questionnaires, 174 were completed and returned. Fourteen were rejected because of incompleteness of the responses, leaving 160 questionnaires, from 64 percent citizens, 28 percent farmers and 8 percent absentee land owners for the analysis.

Response rate calculated by Dillman's method for a number of mail CV studies are presented in Mitchell and Carson (1989). Most of these studies sent at least two follow-up mailings to those with valid addresses who did not respond to the first mailing. However, the low response rate in Bear Creek survey was due to the time of the survey, which was conflicted with spring planting activities.

Descriptive Statistics

Data from the questionnaires were entered into the Reflex Plus database using a Macintosh computer and were subsequently transferred to the Iowa State University mainframe computer system. The basic statistical analyses were carried out in using mainframe SAS computer package. The SAS system is a computer system of software products for statistical data analysis.

The sample distribution of various activities was studied and respective sample percentages were analyzed. Estimations of population parameters were not made using the sample distribution. Therefore, the analysis presented here is mainly based on the investigated sample, but not based on the total population.

The use of Bear Creek People living in the Bear Creek watershed use it for a very limited number of purposes. Use of the creek for recreational purposes is very minimal because of the low volume of water and the low flow rate during a normal season. Uses of the creek, for other activities is indicated by the following sample: 44 percent used it for nature appreciation and viewing wildlife, 29 percent for draining excess water from crop fields by tile lines, 6 percent for livestock water uses, 1 percent for fishing, 2 percent for drinking water, and none for swimming.

Farming activities The total farming area owned by an individual, under various agricultural crops, varies from 12 acres to 2020 acres. The average size of a farmland is about 310 acres. Lands larger than 100 acres in size represent about 85 percent of the total sample. Various other information on crops; conservation measures; agricultural inputs; rate of use of fertilizer; manure; herbicides; and other pesticides; livestock activities; waste handling systems; and tillage practices for different crops was collected at the same time.

<u>Sources of water pollution</u>   To obtain their opinion concerning the possible sources of water pollution in Iowa rivers and streams in general, and Bear Creek in specific, respondents were asked for their opinion on a scale between 0 to 10. A value of 0 means that there is no damage to water resources by the source, the value of 1 means that the item is a minor source of water pollution, and a value of 10 means that it is a very crucial source of water pollution. The mean value of each potential source of pollution, in reference to Iowa as a whole, and in the Bear Creek area specifically, is reported in Table 4.1.

About 68 percent of the sample proportions have identified municipal sewage from cities and towns as an important to very important (between 5 to 10 in the scale) potential source of Iowa's water pollution. In the BC area, about 48 percent of the respondents indicated that municipal sewage is an important source of NPS pollution. Drainage from mines (coal, iron, etc.) is not a very crucial source for Iowa and the BC area. Runoff from roads is a significant source in Iowa as reported by the 38 percent of the sample. Interesting differences and similarities were found between Iowa in general and the BC area specifically. Respondents

Table 4.1. Important sources of water pollution

Sources	Iowa Mean[a]	Iowa Percent[b]	BCW Mean	BCW Percent
Municipal sewage	5.87	68	4.64	48
Drainage from mines	3.60	40	2.25	17
Run-off from roads	3.85	38	2.95	25
Run-off from drains	4.65	53	4.45	48
Landfills	5.30	60	3.82	35
Farm chemicals	6.68	79	6.89	77
Soil sediments	6.17	72	6.26	68
Development activities	4.70	58	3.14	32
Illegal dumping	6.05	63	4.93	43
LUST[c]	5.41	60	3.80	34
Animal & feedlots	4.89	58	4.77	53
Agricultural activities	4.65	50	4.30	43
Aquifer penetration	4.31	44	3.48	35

[a]Average value reported for each category on a scale of 0 to 10.

[b]Major sources reported by the sample respondents. They have identified the influence of each sources by ranking between 5 and 10, in a scale of 0 to 10.

[c]Leaking underground storage tanks.

generally agreed that farm chemicals, soil sediments, animal feedlots, and runoff from storms were major pollutants. However, BC residents generally did not think municipal sewage, and mine drainage were as great a pollutant problem they are elsewhere in Iowa. However, only 25 percent considered runoff significant in the BC area. Runoff from storm drains adds pollution to Iowa according to 53 percent of respondents. The magnitude of the same source in BC is area only 47.8 percent. According to 60.1 percent of the sample, Iowa has been polluted by leaching from landfills. However, only 35 percent agree that leaching is a main cause of polluted water in BC area. Being an agricultural area, fertilizers, manure, and pesticides applied to farmland emerge as a very crucial source of pollution. The proportion of 78.5 percent of the sample agreed on this as a potential pollution source in Iowa generally and 77 percent of the sample in the BC area. Soil sediment is another important potential source of water pollution in many agricultural areas of the world. This is true both in Iowa generally and in the Bear Creek area. Runoff from developments such as parking lots and building sites, are insignificant sources. Illegal dumping of waste in to water in Iowa generally is an important source to 63.7 percent of the sample, but it is not important in the BC area. However, leaking underground storage tanks (LUST) seemed to be a very important source when considering entire state.

It was found that the majority agreed that, animal confinement/feedlot operations were a potential source of water pollution in Iowa. Agricultural support activities however, such as grain elevators and fertilizer depots were not considered important sources by half of the sample. This was further supported in the BC area by 56.8 of the sample. Aquifer penetrations such as sinkholes and surface mines were not influential sources in Iowa according to 56.3 percent of the sample. Agricultural related activities were considered more prevalent sources for potential water pollution in the BC area than in Iowa generally.

<u>Perception of surface water quality</u> Several questions were asked to obtain the respondent's perceptions about surface water quality using the water quality ladder. A scale from 0 to 10 was used with the best water quality being at 10 and the worst 0. About 74 percent of the respondents indicated that surface water quality level is now between 5 and 7. Only about percent agreed that surface water quality now available is suitable for drinking purposes.

About 90 percent agreed that the expectations of future surface water quality should be between level 7 and 10. Nearly 40 percent of the sample required that the best water quality be suitable for human consumption. This acceptable level of water quality can be achieved only by 20-100 percent reduction in prevailing sediments, fertilizer runoff and herbicide runoff, according to the sample response.

Perception of groundwater quality People in Story and Hamilton counties rely on ground water as their primary source of drinking water (Kelley 1990). Nearly 50 percent of them depend on their own ground water wells for household water. The depth of the wells range from 45 to 360 feet. About 3 percent of the sample draw water from artesian (flowing) wells. Average depth of a well in the area is about 132 feet where water is in shallow alluvium aquifers and deeper bedrock aquifers. The source of drinking water for another 43 percent of the sample is municipal water which also is pumped from the deep bedrock and shallow aquifers. Therefore, 92 percent of the sample depends totally on ground water sources for drinking water. Those who obtain water from a municipal water source, considering only the price they pay each month for water and excluding monthly sewage charges pay an average annual water bill of $180 the range being from $25 to $720. Only about 16 percent of the sample ranked the water quality as suitable for human drinking purposes, using the same water quality ladder. Another 72 percent indicated that the water quality level is between 5 and 9.

Vegetative buffer strip The possible use of VBS established along riparian zones has been generally accepted by a majority of the sample as a possible land management practice designed to remove suspended and dissolved contaminants from the overland flow of water prior to entering into surface water and ground water sources. Sixty-one percent of those sampled strongly agreed that the VBS would reduce sediment entering stream. The distribution of the sample is shown in Table 4.2.

The same level of acceptances were not shown for VBS as a measure to reduce pesticide runoff, nitrate pollution, and streambank damage. VBS, as a measure to control pesticide runoff into a stream, was strongly accepted by 44 percent of the sample. The sample proportion of 11 percent, was not sure whether the VBS would absorb nitrate pollution in the root zone. However, 32 percent of the sample strongly agreed that a VBS would control nitrate pollution in the root zone. Only 12 percent rejected the idea of VBS as a control measure to pesticide runoff. About 11 percent of sample respondents strongly agreed with the practice of planting crops up to the edge of a stream. A total of 70 percent of the sample either

Table 4.2 Reduction of sediments by a VBS

Sample response	Frequency	Percent
Strongly disagree	1	0.7
Somewhat disagree	1	0.7
Neutral	13	7.6
Somewhat agree	38	26.4
Strongly agree	88	61.1
Uncertain	5	3.5
Total	144	100.0

somewhat or strongly disagreed with the practice. More than 80 percent of the sample supported the effectiveness of a VBS to control streambank damage. The respondents, perspective of using a VBS in combination with other measures is shown in Table 4.3. This response indicates the acceptability of a VBS in combination with measures as effective ways to control agricultural pollution. Further, the sample proportion of 80 percent agreed that conservation tillage is effective at reducing erosion and sedimentation. Practices such as contour planting and terracing are measures of controlling erosion and sedimentation also were identified by 88 percent and 85 percent of the samples, respectively. Table 4.4 presents the

Table 4.3 Use of a VBS in combination with one or more other conservation measures

Sample response	Frequency	Percent
Strongly disagree	0	0.0
Somewhat disagree	2	1.4
Neutral	13	9.0
Somewhat agree	29	20.0
Strongly agree	93	64.1
Uncertain	8	5.5
Total	145	100.0

Table 4.4 Effectiveness of combination of other measures than a VBS to improve water quality

Sample response	Frequency	Percent
Strongly disagree	6	4.1
Somewhat disagree	18	12.4
Neutral	38	26.2
Somewhat agree	30	20.7
Strongly agree	38	26.2
Uncertain	15	10.3
Total	145	100.0

results of a comparison of VBS with other measures in terms of effectiveness to control pollution.

Data from Table 4.4 indicate that 47 percent of those sampled agreed with the effectiveness of other soil conservation measures to control agricultural pollution. Although the VBS is a relatively new concept, the majority expressed their willingness to adopt. About 87 percent of the sample agreed that they would establish a VBS if they owned farmland adjacent to BC. An acceptable cost share to finance the establishment and maintenance of VBS reveals that farmers should contribute a larger share than other parties. The federal, state and, county shares should be equal. Incentive programs such as tax breaks, and credits are the preferred ways to ensure the voluntary establishment of VBS.

The minimum amount that farmers were willingness to accept (WTA) for voluntary establishment of a VBS averaged $568 per annum per acre. The acceptable values ranged from $0 to $1800.

Social action plan To see how much interest there would be in a grass roots nongovernmental organization by individuals living in the Bear Creek watershed, answers to questions concerning a voluntary, citizens action group called the Creek Team Program (CTP) were analyzed. The purpose of the CTP is to improve or maintain the quality of the water in

Bear Creek. The program works at the grass roots level and provides many benefits for citizens living in the BC watershed. For example, the program could be used to educate others about BC, about the benefits and functioning of a VBS, and to help determine acceptable ways to improve or maintain water quality in BC and other waterways flowing through Iowa's agricultural landscape.

About 50 percent of the sample indicated their willingness to participate in one or more activities listed under the CTP. Some of the very attractive activities are monitoring water quality, planting stream-side trees, shrubs, and grasses, rehabilitating older plantings, clean-up debris in the creek, and stocking fish habitat. The average number of days per year that respondents would be willing to spend in involved with a CTP, is two days. About 33 percent of the respondents agreed to contribute 5 days each year to the CTP.

About participants Section eight of the questionnaire was used to collect some information about participants. The age range and distribution of the sample, as shown in Table 4.5, indicate respondents were from 18 to 90 years of age with the average age being 52 years. The majority of sample respondents were males (78 percent). About 86 percent of the respondents had four or fewer family members. Most had lived

Table 4.5 Age distribution of the sample

Age group	Percentage of the sample
below 29	3
30 - 39	23
40 - 49	24
50 - 59	18
60 - 69	14
70 - 79	11
over 80	7
Total	100

in their present location are average of 22 years, with a range of 0 to 70 years. About 60 job categories were found in the sample indicating the great diversity of the sample background. The average educational level ranged from some college education to a bachelor's degree with about 30 percent having either a bachelor's, a master's or other professional degree. Total household gross income in 1991 for survey respondents averaged from \$30,000 to \$39,999. About 79 percent of the sample earned a gross income of \$20,000 to \$75,000 in 1991.

Analysis and Results

Analysis of the WTP responses and related statistics were carried out using different econometrics techniques. The object of this approach was not only to obtain WTP values but to compare and analyze various estimation techniques and their suitability under different situations.

First, the mean bid values of WTP were estimated for surface and ground water using SAS statistical package. WTA bid values for adopting VBS also were estimated at the same time. The same analysis was extended further to obtain the influence of other independent variables to the WTP values using OLS procedures. As explained in the theory chapters, a WTP function can be estimated using limited dependent variables. The dichotomous choice dependent variable (yes = accept WTP value stated) takes only two values, either 0 or 1. The analysis of such variables can be performed using the Maximum Likelihood Procedure (MLE).

The second analysis includes estimating LPM, Logit, and Probit using MLE procedures. The LPM can be estimated by any multiple regression program. As for the Logit and Probit models, the SHAZAM program (mainframe version) was used. The third approach is quite different from the first two. The numerical integration of the area under the cumulative density function would provide the WTP values for DC dependent variables.

Bid Values - OLS Procedures

WTP bid values were calculated using the open-ended WTP question and the other relevant socioeconomic-demographic variables. OLS procedures available in SAS were used for the analysis. The dependent variable in the open-ended format is the actual dollar amount each respondent would pay. Using the OLS procedure, calculated were the averaged WTP for surface and ground water, and the coefficient for each independent variables. These variables shows their influence to the dependent variable. The equation (3.34) was estimated for the open-ended format WTP question and independent variables given in the equation. Because there was no *a priori* information about the choice of a functional form, the bid curve (3.34) was estimated in this section assuming a linear form.

The average annual WTP estimated for improved surface water quality was $49, and for ground water was $80. If the surface water quality is directly related to VBS and other crop management practices, one could hypothesize that the WTP values are a payment price for those practices. Higher price for ground water over surface water has few justifications. Many Iowans depend on ground water as their primary source of drinking water and, therefore, are willing to pay a high price to keep it clean. About 92 percent of those who responded to the survey use their own wells or municipal water pumped from ground water wells. Beck et al. (1991) indicated that 80 percent of Story County, Iowa residents rely on ground water as their primary source of drinking water. This water comes from two main sources, unconsolidated surficial aquifers and bedrock aquifers. The cleaning of ground water from pollutants involves a higher expenditure than the cleaning of polluted surface water. Moreover, the higher starting point bid value on the closed-ended ground water question could have influenced the higher open-ended bid value for ground water.

The effect that other socioeconomic independent variables have on the WTP value, holding all other variables constant, was analyzed using OLS procedures. First, the summary statistics reported by the analysis are given in Table 4.6. The description of the variables used are as follows:

sw quality = surface water quality
swq accept = acceptable surface water quality
age = age of the respondent
fam. size = size of the family
location = distance from the creek to the land
duration = duration lived at the present location
job = present job title
education = highest education level
gro income = household's gross income from all sources.

Table 4.6 Summary statistics of the regression model for surface water

Variable	Mean	Parameter	T value
Intercept	---	123.1	1.2
SW quality	5.9	-15.1	-3.2
SWQ accept	8.3	18.1	3.3
Age	52	-1.5	-1.9
Fam. size	3.0	15.5	8.2
Location	5.5	0.1	0.1
Duration	22	1.3	1.7
Job	---	1.5	1.9
Education	---	0.8	0.1
Gro. income	---	-17.9	-2.3

The OLS estimation provides unit changes, which can be interpreted directly so that the marginal elasticities and other calculations for policy purposes may be estimated. The resulting equation for WTP for surface water is given below.

$$WTP_{SW} = 123.11 - \underset{(4.81)}{15.09^{**}}[swquality] + \underset{(5.45)}{18.11^{**}}[swqaccept] \qquad (4.1)$$

$$-\underset{(0.75)}{1.45^{*}}[age] + \underset{(8.15)}{15.50^{*}}[fmlsize] + \underset{(0.76)}{1.26}[duration] + \underset{(0.77)}{1.47^{*}}[job]$$

$$+\underset{(7.85)}{0.75}[education] - \underset{(7.93)}{17.91^{**}}[groincome] + \underset{(1.54)}{0.07}[location]$$

$R^2 = 0.7479$ $F = 3.237$ ( ) Standard error

The estimated R^2 value for the model was high, indicating that most of the variation in WTP was explained. Using the above equation, the following information concerning what effect the independent variables have on WTP are determined. The function suggests that, if the current surface water quality increased by one level, the WTP decreases by $15.08, which is a rational behavior. If the water quality is at an acceptable level, the necessity for additional payment is not rational. Similarly, an increase in the future water quality level by one unit increases the WTP value by $18.11. The results indicate that one year's advancement of age reduces WTP value by 1.45. The increase of family size by one person increases WTP value by 15.5. The respondent's duration of living in the area has impact on WTP values, indicating the increase in one year promoting payment by 1.26. Moving up to better jobs increases WTP values; the same is true for education level. Surprisingly, as the gross income levels move up, the WTP values move down. People living far from the creek are willing to pay more money than those who live closer to the creek. Among those variables, the only not significant variables reported are duration of present location, level of education, and the location of the land.

The results for the ground water model indicate different results compared to those of the surface water model. The basic summary statistics are given in Table 4.7. Based on the parameters estimated in the model, WTP relationship is expressed in equation 4.2.

$$
\begin{aligned}
TP_{gw} = {} & -153.9 \underset{(16.4)}{-1.32[gwqnow]} \underset{(21.7)}{+8.65[sources]} \qquad (4.2) \\
& \underset{(2.42)}{-1.64[age]} \underset{(18.6)}{+27.2[famsize]} \underset{(0.36)}{-0.29[welldep]} \underset{(1.93)}{-0.09[job]} \\
& \underset{(28.6)}{+24.9[education]} \underset{(21.3)}{+2.36[groincome]} \underset{(3.95)}{-2.87[location]} \\
& R^2 = 0.4316 \qquad F = 0.828 \qquad (\ \ ) \text{ Standard error}
\end{aligned}
$$

The fit of the ground water model to the data using OLS is not very satisfactory. The estimated R^2 value for the model was very low, indicating that most of the variation in WTP was not properly explained. Moreover, all of the variables used are not significant. Participants' perception about the ground water quality is very high and, therefore, the WTP value decreases, as one could expect.

In general, the OLS procedure is not very appropriate to explain the behavior of the independent variables which could have impacted on the dependent variable.

Estimation of Linear Probability Model

The LPM is used to denote a regression model in which the dependent variable WTP is a dichotomous variable taking the

Table 4.7 Summary statistics of the regression model for groundwater

Variable	Mean	Parameter	T value
Intercept	---	-153.9	-0.7
GW quality	7.3	1.3	0.1
Sources (DW)	---	8.7	0.4
Age	52	1.6	0.7
Fam. size	3.0	27.2	1.5
Location	5.5	-2.9	-0.7
Well depth	132	-0.3	-0.8
Job	---	-0.1	-0.1
Education	---	24.9	0.9
Gro. income	---	2.4	0.1

value 1 or 0. The dependent variable is an indicator variable that denotes the occurrence or nonoccurrence of paying a specified dollar value for protection of water resources. The regression model places no restrictions on the values the independent variables take on except that they not be exact linear combinations of each other. The assumption made here is that the dependent variable is continuous. The independent variables, however, may be continuous, positive, or zero; they may be integers or they may take a dichotomous form.

Results of the OLS regression for DC variables using the SHAZAM Econometrics program are reported in Table 4.8. Except for the coefficient estimates and descriptive statistics, the results seem to be of limited use. Clearly, the implications of the assumptions are very different from the assumptions made in OLS regression. The error term is not assumed to be continuous, homoscedastic or normally distributed. Rather, they are assumed to be dichotomous and dependent upon the parameters and values of the independent variables. Resulting equation for the surface water LP model is as follows:

$$
\begin{aligned}
LPM_{SW} = {} & 0.45 + \underset{(-0.6)}{0.11[swqnow]} + \underset{(2.21)}{0.03^{**}[swqacp]} + \underset{(-1.1)}{0.003[age]} \qquad (4.3) \\
& + \underset{(-0.19)}{0.005[fmlsze]} + \underset{(0.59)}{0.002[locdur]} + \underset{(0.83)}{0.002[job]} \\
& - \underset{(-0.28)}{0.01[edulvl]} + \underset{(1.88)}{0.049^{**}[gincome]} + \underset{(0.63)}{0.0005[loc]} \\
& R^2 = 0.095 \qquad F = 1.747 \qquad (\ \ )\ \text{t-ratio}
\end{aligned}
$$

Significant variables reported in the model are surface water accepted levels and the gross income levels of participants. The other coefficients appear not significant at levels of about 0.5 and 0.1 levels. In particular, the t-ratio for income is 1.8786, which is highly significant, indicating that income does have a positive influence on the WTP values.

Table 4.8 OLS results on surface water DC data

Variable	Descriptive Statistics Mean	Standard Deviation	Variance
WTP$4	----	0.4887	0.2389
swqnow	level 5	2.2872	5.2311
swqacp	level 7	3.3505	11.226
age	52 yrs	16.868	284.51
fam. size	3 members	1.5535	2.4135
duration	20 yrs	16.887	258.18
education	college	1.3269	1.7607
income	$35,000	1.8578	3.4514
location	5 miles	43.523	1894.3

Model: OLS SSE: 3.6030F = 1.747

Dependent variable: WTP_{sw}

R^2 = 0.095 D-W Statistics = 2.1431

MSE: 0.4003 Chi-Square, 3 df 123.4

Variable	Parameter	Std.error	T ratio
intercept	0.4509	0.2614	1.7254
swqnow	0.0111	0.0169	-0.658
swqacp	0.0266	0.0121	2.2049
age	0.0030	0.0028	-1.099
fam. size	0.0053	0.0277	-0.192
duration	0.0016	0.0025	0.5906
job	0.0017	0.0021	0.8262
education	-0.009	0.0343	-0.276
income	0.0486	0.0259	1.8786
location	0.0005	0.0009	0.6265

LPM also applied to the DC data collected for ground water. Results of the OLS analysis for ground water are reported in Table 4.9 and the LP model given below.

$$
\begin{aligned}
LPM_{gw} = {} & \underset{(-2.25)}{0.72-0.028^{*}[gwqnow]}\underset{(-0.38)}{-0.012[sources]}\underset{(-0.88)}{-0.002[age]} \quad (4.4)\\
& \underset{(-0.04)}{-0.001[fmlsze]}\underset{(-0.43)}{-0.001[locdur]}\underset{(1.72)}{+0.0036^{**}[job]}\\
& \underset{(0.11)}{+0.004[edulvl]}\underset{(1.93)}{+0.049^{**}[gincome]}\underset{(1.05)}{+0.0009[loc]}\\
& \underset{(-1.434)}{-0.001[well\ depth]}\underset{(-1.667)}{-0.001[water\ bill]}
\end{aligned}
$$

$R^2 = 0.1511 \qquad F = 2.395 \qquad (\ )$ t-ratio

As in the previous equation, the coefficients can be interpreted similarly to regression with a continuous dependent variable except that they refer to the probability of WTP to a particular dollar amount. In this LPM, few points are worthy of note. First, the reported R^2 of both surface and ground water models is highly misleading. It refers to the explained fraction of the variance of the transformed dependent variable WTP and not to the original variable. However, this can be corrected by using the original variables. By no means does this suggest that the OLS results are better. Rather, it demonstrates the inappropriateness of the R^2 statistic in analysis involving (Dichotomous Choice)

Table 4.9 OLS results on groundwater DC data

Variable	Mean	Descriptive Statistics Standard Deviation	Variance
WTP$10	----	0.4976	0.2476
gwqnow	level 6	3.0857	9.5217
sources	ground	1.2845	1.6500
age	52 yrs	16.868	284.51
fam. size	3 members	1.5535	2.4135
duration	20 yrs	16.887	258.18
education	college	1.3269	1.7607
income	$35,000	1.8578	3.4514
location	5 miles	43.523	1894.3
well depth	58 ft	84.511	7142.0
water bill	$9.00	145.10	21054

Model: OLS SSE: 5.9508 F = 2.395
Dependent variable: WTP_{gw}
R^2 = 0.1511 D-W Statistics = 1.9545
MSE: 0.5410 Chi-Square, 1 dof 77.18

Variable	Parameter	Std.error	T ratio
intercept	0.7188	0.2547	2.8224
gwqnow	-0.028	0.0126	-2.246
sources	-0.012	0.0316	-0.375
age	-0.002	0.0028	-0.877
fam. size	-0.001	0.0283	-0.041
duration	-0.001	0.0025	-0.430
job	0.0036	0.0021	1.7138
education	0.0037	0.0343	0.1081
income	0.0494	0.0255	1.9343
location	0.0009	0.0009	1.0507
well depth	-0.001	0.0005	-1.434
water bill	-0.001	0.0003	-1.667

limited dependent variables. The most important criticism is with the formulation itself: that the conditional expectation be interpreted as the probability that the event will occur. In many cases, this can lie outside the limits zero and one. A practical solution is to truncate the estimates of values close to zero or one. Second, the sum of squared errors has a useful interpretation beyond that in analysis involving qualitative variables. However, with all these difficulties, good and bad LPM results appear quite acceptable within the limitation.

Estimation of Probit Model

There are a variety of reasons the assumption that a probability model is linear in the independent variables is unrealistic in most cases. Moreover, if the model is specified as linear by mistake, the statistical properties derived under the linearity assumption will not generally hold. The parameters being estimated may, indeed, be relevant. The obvious solution to this problem is to specify a nonlinear probability model using MLE procedures in place of a linear probability model. Probit model parameter estimation for the data is one step of estimating the nonlinear prob ability model. The same data are examined later with the Logit model. Tables 4.10 and 4.11 contain the results from a

Probit analysis for DC WTP data. The analysis was made by using the SHAZAM Econometric Program accessible through the Wylbur system in the mainframe computer.

Tables 4.10 and 4.11 contain the results from a Probit program for surface water and ground water, respectively. In both cases, the tables are nearly an exact reproduction of the actual printout to illustrate the behavior of the variables. The SW model yielded an R^2 value of about 0.1079 and GW model about 0.1787. R^2 measure or the goodness-of-fit measure is a summary statistic indicating the accuracy with which a model approximates the observed data. When the dependent variable is qualitative, the accuracy of the model can be judged either in terms of the fit between the calculated probabilities and observed response frequencies or in terms of the model to forecast observed responses. In the case of binary dependent variable such as WTP, the direct R^2 measure can be used for the same purpose. Note that the predicted value of WTP is a probability, whereas the actual value is either 0 or 1. Therefore, the correlation between the WTP binary dependent variable and a probabilistic predictor are measured by the R^2 values, 0.108 and 0.180. Although these values are very low, it does not negate the accuracy of the model. Morrison (1972) argued that the low R^2 values one usually obtains when

Table 4.10 MLE results for Probit model on WTP-SW data

Number of Observations 160 (WTP=0: 62, WTP=1:98)

Iteration Number	Log of Likelihood function
0	-106.82
3	-98.503
6	-97.296

The iteration has converged at 7

Coefficient	ML Estimate	Standard Error	T-Ratios
swqnow	-0.0317	0.0464	-0.6844
swqacp	0.0659	0.0335	1.9711
age	-0.0091	0.0074	-1.2113
fam.size	-0.0207	0.0775	-0.2672
duration	0.0036	0.0071	0.5031
job	0.0045	0.0058	0.7634
education	-0.0274	0.0926	-0.2960
income	0.1376	0.0710	1.9363
location	0.0848	0.0599	1.4146

Likelihood Ratio 19.0463 with 9 df, R^2=0.108, D-W=2.13

Table 4.11 MLE results for Probit model on WTP-GW data

Number of Observations 160 (WTP=0: 70, WTP=1: 90)

Iteration Number	Log of Likelihood function
0	-109.65
6	-93.670

The iteration has converged at 7

Coefficient	ML Estimate	Standard Error	T-Ratios
gwqnow	-0.0820	0.0358	-2.2884
sources	-0.0193	0.0859	-0.2244
age	-0.0075	0.0076	-0.9785
fam.size	-0.0171	0.0808	-0.2109
duration	-0.0046	0.0071	-0.6421
job	0.0092	0.0061	1.5099
education	0.0102	0.0975	0.1050
income	0.1462	0.0726	2.0127
location	0.1429	0.0760	1.8815
well depth	-0.0024	0.0014	-1.7168
water bill	-0.0013	0.0008	-1.4951

Likelihood Ratio 31.9613 with 11 df, R^2=0.18, DW=1.94

calculating correlation between a binary dependent variable and the predicted probabilities need not imply that the model is not good. Significant variables reported in the surface water Probit model are shown in equation (4.5).

$$\begin{aligned}
\text{Probit}_{sw} = & -0.14 \underset{(-0.68)}{-0.03[\text{swqnow}]} \underset{(1.97)}{+0.07^{**}[\text{swqacp}]} \underset{(-1.21)}{-0.009[\text{age}]} \qquad (4.5) \\
& \underset{(-0.27)}{-0.02[\text{fmlsze}]} \underset{(0.50)}{+0.004[\text{locdur}]} \underset{(0.76)}{+0.052[\text{job}]} \\
& \underset{(-0.30)}{-0.03[\text{edulvl}]} \underset{(1.94)}{+0.14^{**}[\text{gincome}]} \underset{(1.41)}{+0.09[\text{loc}]}
\end{aligned}$$

$R^2 = 0.108$ D-W = 2.13 ( ) t-ratio

Results indicate that only swqacp and gincome are significant variables in the model. The expected signs and the significance of the variables are exactly similar to the results given in LPM model for surface water. The result for groundwater is given in equation (4.6).

$$\begin{aligned}
\text{Probit}_{gw} = & \ 0.52 \underset{(-2.28)}{-0.08^{*}[\text{gwqnow}]} \underset{(-0.22)}{-0.019[\text{sources}]} \underset{(-0.98)}{-0.008[\text{age}]} \qquad (4.6) \\
& \underset{(-0.22)}{-0.02[\text{fmlsze}]} \underset{(-0.64)}{-0.005[\text{locdur}]} \underset{(1.51)}{+0.009[\text{job}]} \\
& \underset{(0.11)}{+0.01[\text{edulvl}]} \underset{(2.01)}{+0.15^{**}[\text{gincome}]} \underset{(1.88)}{+0.14^{**}[\text{loc}]} \\
& \underset{(-1.72)}{-0.003[\text{well depth}]} \underset{(-1.50)}{-0.001[\text{water bill}]}
\end{aligned}$$

$R^2 = 0.18$ D-W = 1.94 ( ) t-ratio

Results are identical with the LPM ground water results except for the location variable, which is being reported as significant in the Probit analysis.

Estimation of Logit Model

Probability models are, as a rule, estimated from survey data, which provide large samples of independent observations with a wide range of variation of the regressor variable. One of the preferred methods of estimation is Logit. This permits the estimation of the parameters of almost any analytical specification of the probability function; in addition, it yields estimates that are consistent and asymptotically efficient with ready estimates of their asymptotic covariance matrix.

Like the Probit model the Logit uses an iterative scheme, which is supplemented by starting values for the parameter vector and by a convergence criterion to stop the process. As for the convergence criterion, the iterative process stops when successive parameter values are nearly equal or when the score vector comes quite close to zero. Most program packages such as SHAZAM employ default convergence criteria that are absurd in view of the precision of the data and of the statistical precision of the final point estimates. Those estimates for surface and ground water are given in Tables

4.12 and 4.13. With reasonable data and a reasonable computer program, convergence should be achieved in something like five or, at the outermost, ten iterations.

If the number is much larger, something is wrong. At fault may ill-conditioned data with an almost singular regressor matrix, with regressors of widely different order of magnitude, or with the sample frequency of the attribute under consideration very close to 0 or 1. However, in all cases of Probit and Logit we found that the number of iterations is below 8. The Logit equations for surface and ground water parameter estimation are given below.

$$\begin{aligned} \text{Logit}_{SW} = & \underset{}{-0.19}\underset{(-0.67)}{-0.05[\text{swqnow}]}\underset{(1.95)}{+0.11^{**}[\text{swqacp}]}\underset{(-1.19)}{-0.015[\text{age}]} \qquad (4.7) \\ & \underset{(-0.32)}{-0.04[\text{fmlsze}]}\underset{(0.48)}{+0.006[\text{locdur}]}\underset{(0.75)}{+0.007[\text{job}]} \\ & \underset{(-0.31)}{-0.05[\text{edulvl}]}\underset{(1.94)}{+0.23^{**}[\text{gincome}]}\underset{(1.44)}{+0.15[\text{loc}]} \\ & R^2 = 0.108 \qquad \text{D-W} = 2.13 \qquad (\ \ )\ \text{t-ratio} \end{aligned}$$

As in the Probit results, the only significant variables are swqacp and the gincome. Reported values for R^2 and the D-W statistics are identical. The similar situation for ground water is given in equation (4.8).

Table 4.12 MLE results for Logit model on WTP-SW data

Number of Observations 160 (WTP=0: 62, WTP=1:98)

Iteration Number	Log of Likelihood function
0	-106.82
3	-98.639
6	-97.328

The iteration has converged at 7

Coefficient	ML Estimate	Standard Error	T-Ratios
swqnow	-0.0509	0.0764	-0.6669
swqacp	0.1066	0.0548	1.9458
age	-0.0150	0.0126	-1.1902
fam.size	-0.0416	0.1304	-0.3188
duration	0.0056	0.0117	0.4752
job	0.0072	0.0095	0.7522
education	-0.0467	0.1518	-0.3077
income	0.2279	0.1177	1.9358
location	0.1446	0.1003	1.4411

Likelihood Ratio 18.9813 with 9 df, R^2=0.108, D-W=2.13

Table 4.13 MLE results for Logit model on WTP-GW data

Number of Observations 160 (WTP=0: 70, WTP=1: 90)

Iteration Number	Log of Likelihood Function
0	-109.65
7	-93.707

The iteration has converged at 8

Coefficient	ML Estimate	Standard Error	T-Ratios
gwqnow	-0.1343	0.0610	-2.1999
sources	-0.0329	0.1420	-0.2319
age	-0.0126	0.0130	-0.9761
fam.size	-0.0329	0.1366	-0.2410
duration	-0.0072	0.0119	-0.6051
job	0.0148	0.0101	1.4641
education	0.0171	0.1574	0.1084
income	0.2429	0.1208	2.0087
location	0.2339	0.1240	1.8856
well depth	-0.0040	0.0024	-1.6938
water bill	-0.0021	0.0014	-1.4613

Likelihood Ratio 31.8868 with 11 df, R^2=0.18, DW=1.94

$$\text{Logit}_{gw} = \underset{}{0.89} - \underset{(-2.21)}{0.13^{*}}[\text{gwqnow}] - \underset{(-0.23)}{0.033}[\text{sources}] - \underset{(-0.98)}{0.013}[\text{age}] \quad (4.8)$$

$$- \underset{(-0.24)}{0.03}[\text{fmlsze}] - \underset{(-0.61)}{0.007}[\text{locdur}] + \underset{(1.46)}{0.015}[\text{job}]$$

$$+ \underset{(0.11)}{0.02}[\text{edulvl}] + \underset{(2.01)}{0.25^{**}}[\text{gincome}] + \underset{(1.89)}{0.24^{**}}[\text{loc}]$$

$$- \underset{(-1.69)}{0.004}[\text{well depth}] - \underset{(-1.46)}{0.002}[\text{water bill}]$$

$R^2 = 0.18$ D-W = 1.94 ( ) t-ratio

This result is also identical to the results given in equation (4.6) for ground water by the Probit model. Results obtained by the Probit and Logit models show similar values for parameters estimated and for the values such as R^2 D-W ratio, and the Likelihood ratios.

Comparison of LPM, Probit and Logit Results

The Probit and Logit forms were used as alternatives to the LPM for qualitative dependent variables, which contains only yes or no answer. Direct comparisons among the three sets of estimates enables to determine the effectiveness of each method. Many instances the three sets of coefficients reported in the two tables are quite similar, particularly those of the Probit and Logit models. In many applications of the LPM, Probit and Logit models, it happens that the number of observations in one of the groups is different compare to the other group.

In such cases, it has been often suggested that one should use weighted LPM, Probit and Logit models similar to the weighted least square method. However, in this analysis the same data set has been used in all three analyses, except for the surface and ground water applications. Table 4.14 and 4.15 shows the results of direct comparisons among the three estimations procedures obtained from surface and groundwater situations.

The significant difference emerging in the surface water model is the constant term, which consists of negative values for Probit and Logit. Even for those models, although one cannot derive the results analytically, it appears that the slope coefficients are not much affected by unequal sampling rates. However, weighing the observations is the correct procedure if there is a problem of heteroskedasticity. If the interest is mainly in examining which variables of a model are significant, it is not wise to make any changes in the estimated coefficients. On the other hand, if the estimated model is going to be used for prediction purposes, an adjustment in the constant term is necessary.

Table 4.14 Comparison of LPM, Probit and Logit estimates for surface water data

Variable	LPM	Probit	Logit
swqnow	.01(-.66)	-.03(-.68)	-.05(-.67)
swqacp	.03(2.2)	.07(1.9)	.11(1.9)
age	.003(-1.1)	-.009(-1.2)	-.02(-1.2)
fam. size	.005(-.19)	-.02(-.27)	-.04(-.32)
duration	.002(.59)	.004(.50)	.006(.48)
job	.002(.83)	.005(.76)	.007(.75)
educat.	-.009(-.28)	-.03(-.30)	-.05(-.31)
income	.05(1.9)	.14(1.9)	.23(1.9)
location	.001(.63)	.08(1.4)	.15(1.4)
constant	.45	-.14	-.19
R^2	.095	.108	.108
D-W stat	-	2.130	2.130
F value	1.747	-	-
Chi-Sq.	123.400	-5.890	-5.890

( ) t-ratio

Table 4.15 Comparison of LPM, Probit, and Logit estimates, for ground water data

Variable	LPM	Probit	Logit
gwqnow	.03(-2.2)	-.08(-2.3)	-.13(-2.2)
sources	-.01(-.38)	-.02(-.22)	-.03(-.23)
age	-.002(-8.8)	-.008(-9.8)	-.01(-.98)
fam. sz.	-.001(-.04)	-.02(-.21)	-.03(-.24)
dura.	-.001(-.43)	-.005(-.64)	-.007(-.61)
job	.004(1.7)	.009(1.5)	.01(1.5)
educat.	.004(-.11)	.01(.11)	.02(.11)
income	.05(1.9)	.15(2.0)	.24(2.0)
location	.001(1.1)	.14(1.9)	.23(1.9)
well dep	-.001(-1.4)	-.002(-1.7)	-.004(-1.7)
wat. bil	-.001(-1.7)	-.001(-1.5)	-.002(-1.5)
constant	.72	.52	.89
R^2	.15	.18	.18
D-W stat	-	1.94	1.94
F value	2.395	-	-
Chi-Sq.	77.2	-6.9	-6.9

The regression coefficients of WTP on all other variables for surface and ground water reported in Tables 4.14 and 4.15, show that some coefficients have signs opposite those one could expect. Significant variables reported in the surface water model are swqacp and the level of income. These results indicate that the accepted surface water quality level would be in the creek and the level of income variables have a positive effect on the probability of accepting the WTP amount specified for surface water quality improvement. These two variables are significantly positive. However, in the ground water model income, and the location of the land, variables are positively significant. This indicate that with higher income more support for positive WTP values. Generally, the location of the respondents' house and lands is the key factor in surface water sources, in order to obtain the full benefits such as clean water, recreation, and the environment. However, in ground water, there are no such benefits attributed to the location because aquifers could be extended to any distance.

The coefficients of the Logit model should be approximately four times the coefficients of the LPM (Maddala, 1988). Logit coefficients reported in Tables 4.14 and 4.15, are about four times the LPM coefficients. This is proof of the better fits of the model by all three procedures. R^2 and other summary statistics indicate that there is not much choice between the Logit and Probit models, and that both are better than the LPM. For the two estimation techniques of Probit and Logit, the chi-square statistics for surface and ground water are essentially the same. In short, comparison of both goodness of fit values and individual parameter estimates, indicate that there is very little difference between the two procedures.

Numerical Integration Procedure

The shaded area in the graph shown in Figure 3.4, represents the expected WTP for the water quality improvement. This is a Hicksian equivalent measure of welfare change expressed in the equation (4.23). Table 4.16 presents the list of bid values posted for the WTP question given in page 89. The observed proportion of positive responses at each bid places the probability values. The cumulative probability values for different bids give the values of the cumulative density function (CDF).

Assuming the distribution of CDF with respect to bid values takes the functional form F(X) given in equation (4.23), the appropriate Logit model was obtained. The probability of responding no to a price should decrease as the quantity consumed increases. When the conditions given in

Table 4.16 Bid value distribution

Bid Value ($)	Cumulative Probability Surface water	Ground Water
0.0	0.350	0.342
2.0	0.360	0.350
6.0	0.362	0.364
12.0	0.417	0.376
18.0	0.433	0.412
24.0	0.504	0.436
36.0	0.520	0.444
42.0	0.532	0.453
48.0	0.575	0.479
60.0	0.685	0.530
72.0	0.748	0.556
84.0	0.756	0.562
96.0	0.850	0.590
120.0	0.984	0.684
180.0	0.988	0.863
240.0	0.990	0.974
300.0	0.992	0.991
480.0	1.000	1.000

equations (4.25) and (4.26) are met within the range of the data, they guarantee that the Hicksian demand functions are positive and downward sloping. This is a useful result that can influence the choice of the functional form specified above.

Since the yes and no responses to the valuation question are mutually exclusive events, Pr(yes) is equal to one minus Pr(no) and Pr(no) is a cumulative density function (cdf). Therefore, the estimated Logit function can be used to calculate the expected value respondents place on the item being valued.

Hanemann (1984) suggests functional specifications for f(x) that are consistent with utility theory. These theoretical specifications are derived from the theoretical definition of value to be estimated. Two such forms were used in the present study: a linear specification and a polynomial specification. However, these two models are not consistent with any type of conventional utility function and are comparable to the functional specification used by Bishop et al.(1983).

The cdf has been plotted against the bid values using linear and polynomial specifications, which are shown in Figure 4.1 and 4.2.

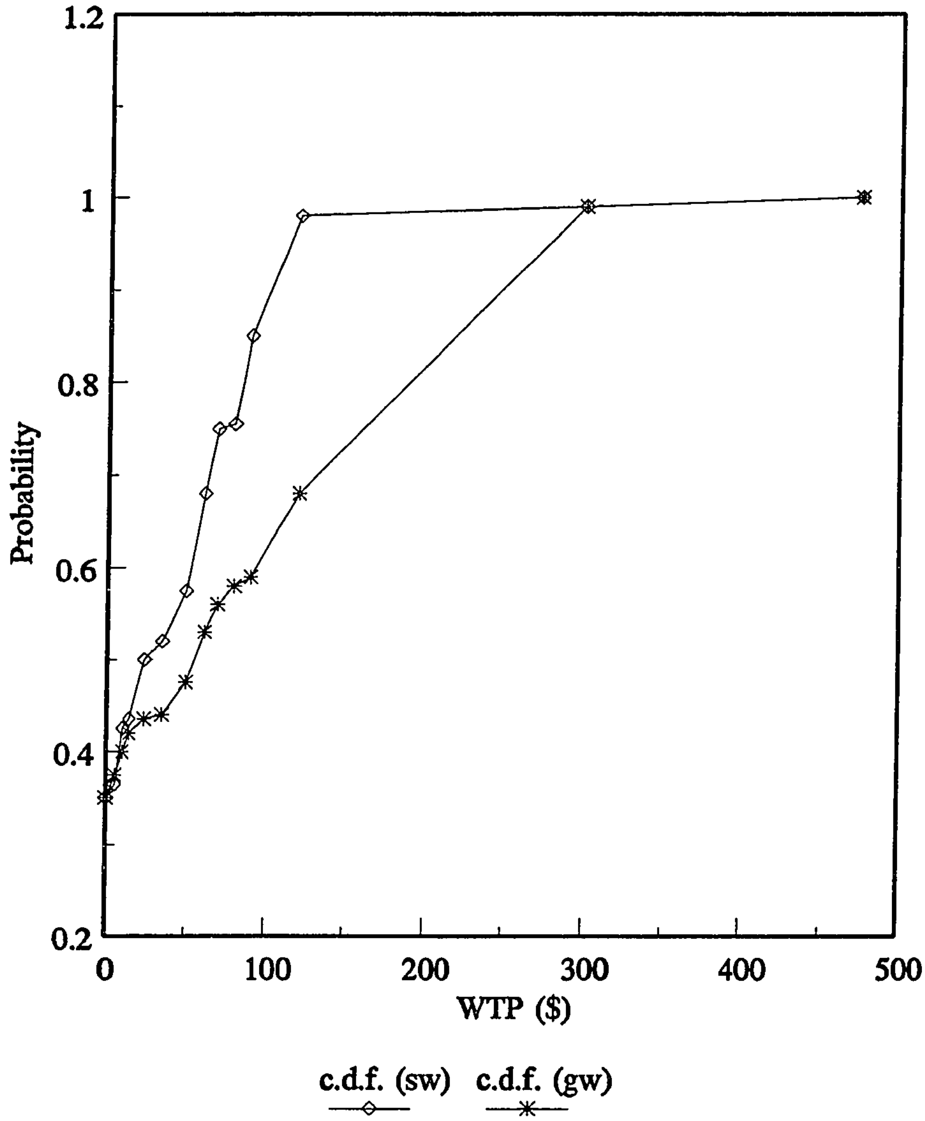

Figure 4.1. Logit curves for SW and GW data

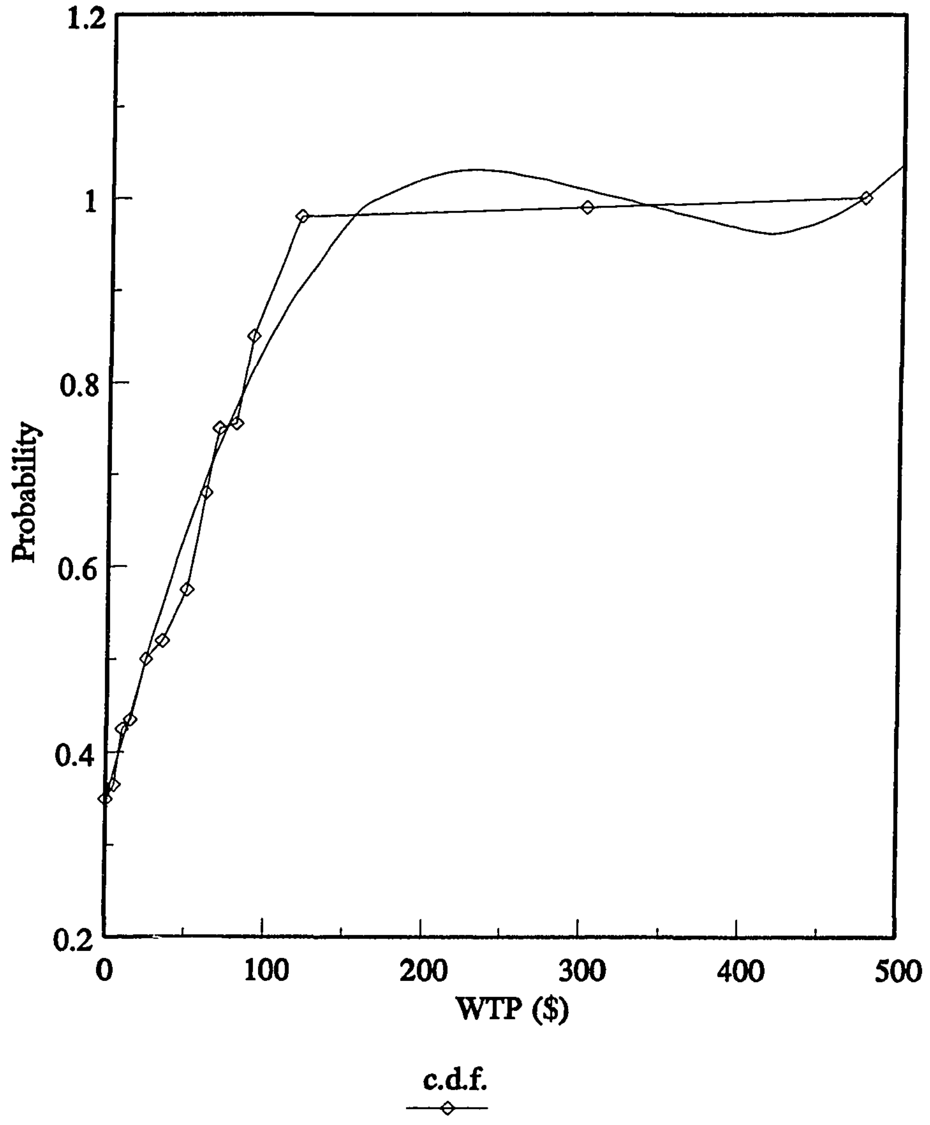

Figure 4.2. Polynomial order 3 for SW data

The distributions of two curves are mostly related to the Logit curve given in Figure 3.4. To obtain the value similar to the shaded area of Figure 3.4, the numerical integration procedure has been used in Figure 4.1 and 4.2. This procedure measures the area under the Logit curve.

Evaluating this function at the sample mean, the median, and the X_{max} leads to a conditional estimate of WTP values. The results of the analysis of linear specification are reported in Table 4.17. Evaluating the function at sample mean at $49 for surface water leads to a conditional estimate of WTP value of $26.43. The same for the ground water is about $43.72. Alternative estimates of values are obtained by truncating the range of integration at median and X_{max}. The WTP value for surface water using the median value is $26, whereas the ground water is $39.47. The truncation at X_{max} provides WTP value for surface water as $44 and for ground water $81.85.

Given the results of the open-ended format and the OLS estimations, and an examination of the data, those estimates appear somewhat reasonable. Since the highest offer in the sample is $480 and the tail of the estimated distribution of Logit function is an artifact of the range of offers, it is impossible to predict accurately

Table 4.17 Results of WTP values from integration

Points of the curve	$Area_{sw}$	$Area_{gw}$
$Mean_{sw=49,\ gw=90}$	22.57	46.28
$Median_{sw=48,\ gw=72}$	22.00	32.53
X_{max} $_{gw=sw=480}$	436.00	398.15

how fast the tail actually approaches the axis beyond the highest data point. The polynomial approach first fit the polynomial curve to the data given in Table 4.16, which is shown in Figures 4.2 and 4.3. An alternative estimate of value is obtained by assessing the polynomial equation at three levels: mean, median and X_{max}. This model considered a usable functional form to derive expected WTP for clean water. Using the above three levels for truncating the range of integration provides the area under the curve for surface and ground water. The value estimates for surface and ground water are summarized in Table 4.18.

The resulting estimate of WTP for surface water at mean level is $30.77, and the estimate for ground water is $72.77. Using the truncation at median value provides WTP

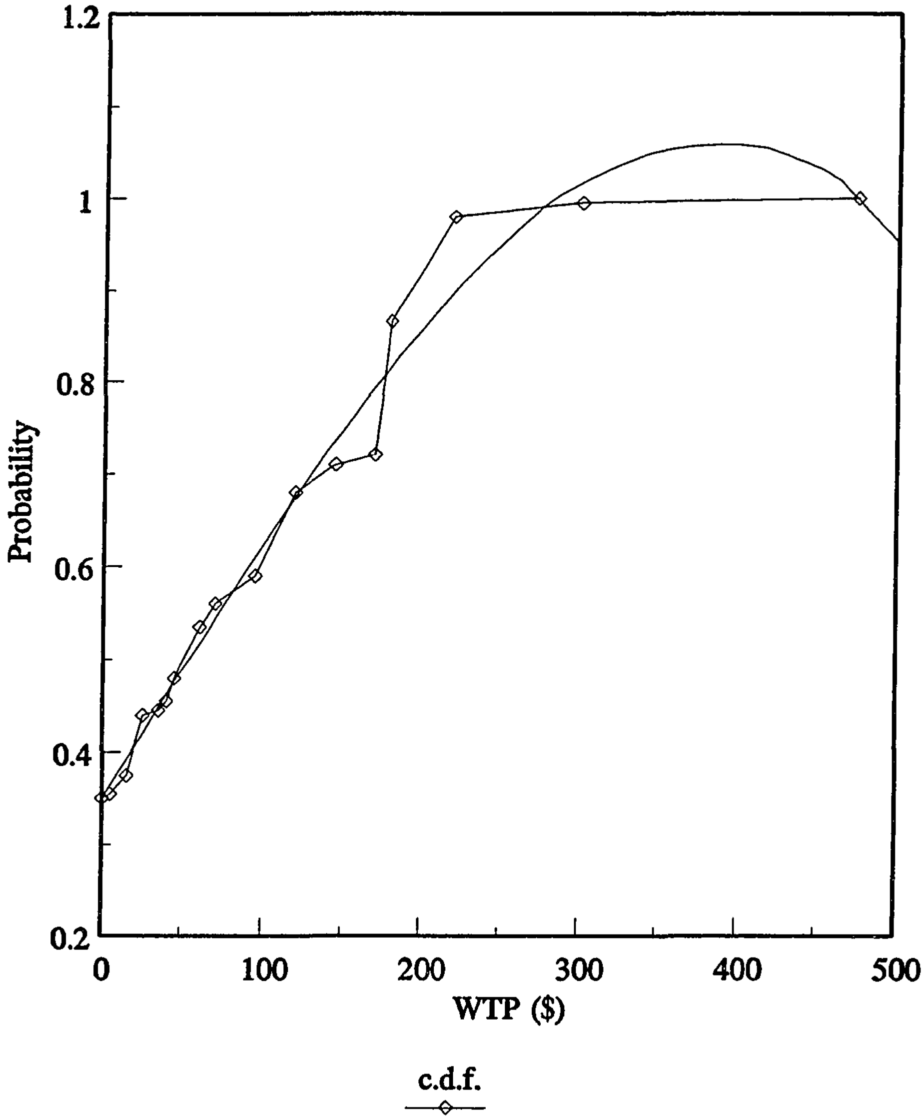

Figure 4.3. Polynomial order 3 for GW data

Table 4.18 Results of WTP values from polynomial curve

Points of the curve	$Area_{sw}$	$Area_{gw}$
$Mean_{sw=49,\ gw=90}$	18.23	26.23
$Median_{sw=48,\ gw=72}$	12.00	28.36
$X_{max\ gw=sw=480}$	321.12	303.25

for surface water as \$36, and ground water \$43.64. The WTP for surface water at X_{max} is \$158.88 and for ground water is \$176.75.

CHAPTER 5 SUMMARY AND CONCLUSION

Iowa, an agricultural state, is facing a serious threat from NPS pollution of its water resources. The dispersed NPS pollution mixes with soil particles from uplands and is deposited in bottomlands where pollutants can enter the aquatic environments of streams, ponds, and lakes. Sediments from the erosion of agricultural lands is the most significant volume of NPS pollution in many parts of the state. This is the most deleterious cause of numerous direct and long-term ecological and economic impacts. In addition, many surface drinking water sources in Iowa have reported nitrate levels above the acceptable level. Several herbicides and pesticides have been detected in shallow aquifers that provide drinking water to many Iowa residents. NPS pollution is, by nature, diffuse and often poorly defined, and beneficiaries of abatement are numerous and broadly distributed. Therefore, the solution to NPS agricultural pollution should be initiated by polluters such as farmers and land owners.

A VBS and other conservation measures are proposed as effective measures to control NPS pollution. A VBS can consist of perennial grasses, shrubs, and tree species all with vigorous growth characteristics, and all purposefully established parallel to waterways along one or both banks. The objectives of the VBS and other measures are to provide localized erosion protection and to filter nutrients, sediments, and chemical pollutants from agricultural runoff.

The main focus of this study was to measure the benefits of environmental improvements from VBS and other management practices, which would control agricultural runoff from farm lands. A methodology of empirical techniques based on underlying economic theory was presented to measure the welfare changes associated with an improvement of water quality. The body of literature shows that even the available empirical estimations of benefits have been based on adhoc procedures, which have lacked an adequate theoretical foundation. CV methodology was proposed to measure the water quality improvement by VBS and other conservation measures.

The idea of CV is to assume that there is a market for clean water filtered by VBS and other conservation measures, and then to ask individuals what they would be WTP for clean water. CV methodology satisfies requirements of economic theory and has been used to generate WTP functions for a large and diverse set of consumer goods.

Accordingly, a mailed survey was used to obtain people's perception about surface and ground water quality, the perceived effectiveness of VBS and other conservation measures to control agricultural pollution, and the individuals WTP measures for such activities. The survey was carried out in the Bear Creek watershed area, located in Story and Hamilton counties, central Iowa.

Being a 7160 ha. watershed, the main use of Bear Creek is limited mainly to appreciation of nature and to drain excess water from crop fields by tile lines and overland flow. Survey results revealed that farm chemicals, soil sediment, animals, and feedlot operations are the main sources of water pollution in Bear Creek. The present level of surface water quality in the creek is perceived to be between five and seven on a scale of zero through ten with ten being the best water quality possible. About 90 percent of those sampled want water quality levels to be raised to between seven and ten. About 92 percent of those sampled depend totally on ground water sources for drinking water. However, only 16 percent of those sampled approved the suitability of the water for drinking purposes. Many believed, that the present levels of water quality lies between level five and nine on the same scale.

The use of VBS was accepted by a majority of those sampled as an acceptable management practice to protect surface and ground water sources. About 61 percent of those sampled strongly agreed that the VBS will reduce sediment from runoff. Totally, about 90 percent agreed that VBS are effective in controlling sediment. However, only 32 percent of those sampled strongly agreed that a VBS will control nitrate pollution in the root zone. Of those sampled, 84 percent agreed that a VBS along with one or more other conservation measures is effective at controlling agricultural pollution. However, 26 percent strongly disapproved of using VBS instead of combinations of other conservation measures.

In general, many have agreed that agricultural pollution, especially sediment, is the biggest problem in Iowa surface water sources and that VBS is an effective method to control agricultural pollution, mainly sediment-related problems. The combination of other conservation techniques with a VBS is effective in controlling NPS pollution.

From the survey, the average annual WTP estimated for clean surface water was $49. If the surface water quality is directly related to VBS and other crop management practices, one could hypothesize using the WTP values as a payment price for those practices. Bishop et al. (1983) summarized the WTP bid value estimates obtained from various studies. It shows that CV estimates ranged from $11 to $101. Many surface water WTP studies reported the magic figure of $40 for clean water. Mitchell and Carson (1989) reported on the famous Sandhill experiments using various bid methods. WTP values reported in these studies ranged from the $30 to the $60. The mean WTP for ground water protection reported in this study was $80 annually.

The numerical integration of Logit curves at various truncation points provided the mean WTP values. Evaluating the Logit function at a sample mean of $49 for surface water leads to a conditional estimate of WTP value of $26.43. The estimate for ground water is about $44. The truncation at X_{max} provided WTP values for surface water as $44 and for ground water as $82. The estimated WTP for surface water using the integration of Polynomial curve is $31, and for ground water is $73 annually. All these estimations provide WTP values around $40 for surface water and the $80 for ground water. By using these mean WTP values along with conservative aggregation procedures, it is possible to estimate total values. The value could have many uses for future water resource planning or to enact policy measures with respect to water resources.

many uses for future water resource planning or to enact policy measures with respect to water resources.

This research has illustrated the implications of the choice of functional form in a Logit model for analyzing contingent valuations of water resources. A linear specification was found to be inappropriate because it implied a wrong direction of the demand curve which is not compatible with the economic theory. Although other specifications are possible, the polynomial form seems superior. Its goodness-of-fit was also very high. However, the results indicate that the choice of a particular functional form can have an important impact on the mean WTP measured from the model.

With the use of procedures of OLS, LPM, Probit, and Logit regression analysis for the above valuation estimates, it was possible to determine the specific socioeconomic characteristics that influence Bear Creek residents' WTP for water resources protection. The respondents' assessed water quality acceptance level, family size, and present jobs positively influenced their WTP, while their gross income, present water quality level, and age had a negative influence. The socioeconomic variables, which were shown to have no statistically significant influence on WTP values, include the number of years they lived in the community, education level, and the location of the land. All variables in the ground water model are statistically insignificant.

The LPM surface water model indicated that surface water quality acceptable level and the gross income positively influence the WTP values, while all other variables are statistically insignificant. However, the LPM ground water model indicated the positive influence for WTP from the variables, gross income, and job level and the negative influence from the present ground water quality levels. All other variables are statistically insignificant.

The only positively significant variables in the Probit surface water model are gross income and the water quality acceptable levels. All other variables are insignificant. The ground water model, is negatively influenced by present ground water quality and positively influenced by gross income, and the location of lands with respect to the Bear Creek. All other variables are insignificant.

Both gross income and the surface water quality acceptable level are significant and positively influence WTP values. All other variables are insignificant. The same two variables are positively influences for ground water model WTP values. The negative influence had been reported for present ground water quality level. All other variables are insignificant. It was found, in many cases, that gross income levels are significantly and positively influenced for WTP values.

There also are several important methodological implications associated this study. First, for those persons interested in conducting similar estimates for environmental amenities, CV methodology as utilized in this study has been demonstrated to be a relatively straightforward methodology to follow. The second implication concerns the variables that influence WTP values. It has been demonstrated that several socioeconomic characteristics influence environmental attitudes and concerns toward the WTP values. In general, people are quite willing to voice support for environmental causes but, when it comes to financial considerations, their support and enthusiasm disappears.

Farmers and citizens in general, perceive that there is a problem with surface and ground water quality in Bear Creek, but vary in their WTP for its improvement. They are more willing to pay for ground water quality improvement but believe the land owners use of VBS will help improve surface water quality. This kind of information is important for professionals and policy makers trying to implement conservation practices at the watershed level.

The CV methodology and econometric techniques described in this analysis were able to measure their WTP for clean water.

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ACKNOWLEDGEMENTS

I would like to express my sincere appreciation to those individuals who have helped me throughout my graduate school years. I especially thank my major professors, Dr. Joe P. Colletti and Dr. Richard Schultz, and members of my committee Dr. T. Al Austin, Dr. Gorden L. Bultena, and Dr. HyIke VandeWetering for their distinguished guidance and tutelage.

My stay in Ames was greatly enhanced by the encouragement and friendship of my fellow students and the staff.

Finally, I would like to thank my wife Janaki, and sons Kanishka, and Ryan, for their constant patience and unceasing encouragement.

APPENDIX
BEAR CREEK WATER RESOURCES SURVEY

SECTION 1: LOCATION AND USE OF BEAR CREEK (BC)

1. Approximately how far if your **home** in town or most of your **land** from BC?

    __________yards or miles
    Also, please mark "X's" on the map on the cover page to show the approximate location(s) of your land.

2. How do your use Bear Creek? Please check all uses that apply to you and to members of your household during the last five years (1987 through 1991).

_____	Fishing	_____	Human drinking water source
_____	Swimming	_____	Crop irrigation water source
_____	Livestock water source	_____	Draining excess water from crop fields by tile lines
_____	Nature appreciation &	_____	Other (specify __________________)

SECTION 2: CURRENT FARMING ACTIVITIES

3. In 1991, were you engaged in **farming full-time or part-time** on or near the Bear Creek watershed located in Story and Hamilton Counties? The study area includes all sections of land indicated on the map on the cover page. (circle your answer)

Yes	----->	**Continue in Section 2**
No	----->	**I am not a full-time or part-time farmer.** **Please go to page 3, Section 3**
No	----->	**I am no longer farming. I quit prior to 1991.**

Who owns the land that you once farmed?__________________
Please go to **page 3, Section 3**

We are interested in knowing about your 1991 farming activities in the BC study area.

4. Acres operated

Crop	Planted acres in 1991
Corn	________
Soybeans	________
Oats	________
Wheat	________
Hay	________
Pasture	________
Grassed Waterways	________
Other	________
Total Area Operated	________

5. Do you grow corn or soybeans on highly erodible land in the BC study area? (circle answer) Yes No

   If yes, do you use different conservation measures on the highly erodible land than on your other farmland? (circle answer) Yes No

   If yes, do you use: (circle answer)

Strip farming?	Yes	No
Contours?	Yes	No
Terraces?	Yes	No
Other (Specify________)	Yes	No

6. Agricultural inputs

Enter **item(s)** used, the **crop** to which it was applied, & the approximate **rate** of use per acre.

Item	Crop applied to	Approx. rate of use (lbs or gal/acre)
Fertilizer(s):		
________	________	________
________	________	________
________	________	________
Manure:		
________	________	________
________	________	________
________	________	________

Herbicide(s):

______________ ______________ ________________________________
______________ ______________ ________________________________
______________ ______________ ________________________________

Other Pesticides (Insecticide(s), Nematicide(s), etc.)

______________ ______________ ________________________________
______________ ______________ ________________________________

7. Livestock activities

a) During 1991, did you have any livestock operations? (circle answer)
Yes ----->**Please answer the rest of the question.** No ----->**Go to Question 8**

Livestock type	Approximate no. of animals	Feedlot acreage	Building size (sq. ft.)
________	________	________	________
________	________	________	________
________	________	________	________

b) What type of waste handling system(s) did you use for your livestock?

____
____
____

8. Tillage Practices

a) For each crop, enter the **number of acres** for each tillage practice used by you in 1991 in BC study area?

Tillage Practices	**Corn**	**Soybean**	**Other**	**Other**
Moldboard plowing	____	____	____	____
Chisel plowing	____	____	____	____
Disking	____	____	____	____
Field cultivating	____	____	____	____
Crop cultivating	____	____	____	____
No-till planting	____	____	____	____

b) If you moldboard plow, then to what depth? ________

c) If you chisel plow, then to what depth? ________

SECTION 3: POTENTIAL SOURCES OF WATER POLLUTION

9. Now we would like your opinion concerning the importance of various sources of water pollution. Using a scale between 1 and 10, please give an **importance rating** for each of the potential sources of water pollution given below. A value of "1" means that the item is an **unimportant source** of water pollution in your opinion and a value of "10" means that is it a **very important** source of water pollution. Do this for Iowa and Bear Creek.

Potential Sources of Water Pollution	**Ranking for Iowa**	**Ranking for Bear Creek**
• Municipal sewage from cities and towns	____	____
• Drainage from mines (coal, iron, etc.)	____	____
• Run-off from roads	____	____
• Run-off from storm drains	____	____
• Run-off and leaching from landfills	____	____
• Run-off from fertilizers, manure and pesticides applied to farmlands	____	____
• Run-off of soil sediments from farmland	____	____
• Run-off from developments (parking lots, building sites, etc.)	____	____
• Illegal dumping of wastes in water	____	____
• Leaking underground storage tanks (gasoline tanks, etc.)	____	____
• Animal confinement/feedlot operations	____	____

Potential Sources of Water Pollution	**Ranking for Iowa**	**Bear Creek**
• Agricultural support activities (grain elevators, fertilizer depots, etc.)	____	____
• Aquifer penetrations (sinkholes, surface mines, etc.)	____	____
• Other (please specify)________________________	____	____

SECTION 4: SURFACE WATER QUALITY IN BEAR CREEK

These next questions relate to the surface water quality that you have observed or know about in Bear Creek. For this purpose, we will use a **Water Quality Ladder**, which considers different water quality standards.

<u>Water Quality Ladder</u>
Best Possible Water Quality
10 -----> Best quality water (drinking water for humans)
9
8
7
6
5
4
3
2
1
0 -----> Unfit for any use (human, wildlife, livestock, & crops)

Please consider the time period from April 1991 through October 1991 for all water quality questions.

10. Using the scale given in the Water Quality Ladder and the period of time in question, please give your opinion of the **quality of the surface water** (the water that you see flowing) in Bear Creek. (circle your answer)

0	1	2	3	4	5	6	7	8	9	10
Unfit										Best

11. Is this water quality (that you circled) suitable for (circle your answer)

Human drinking purposes?	Yes	No
Swimming/recreational activities?	Yes	No
Wildlife and fishing?	Yes	No
Livestock uses?	Yes	No
Crop uses?	Yes	No

If you indicated a water quality level of 10 (the best level) in Q #10, then go right to Q #17. Otherwise continue with Q #12.

12. What water quality level would be **acceptable** to you for the surface water in Bear Creek? (circle your answer)

0	1	2	3	4	5	6	7	8	9	10
Unfit										Best

13. Would this acceptable water quality be suitable for (circle your answer)

Human drinking purposes?	Yes	No
Swimming/recreational activities?	Yes	No
Wildlife and fishing?	Yes	No
Livestock uses?	Yes	No
Crop uses?	Yes	No

Note that in the next set of questions we will be asking for your willingness to pay for certain changes in the water quality of Bear Creek. By giving your response, you will not receive a bill or payment from any government body. We want to get an estimate of the value that you place on changes in water quality.

14. Assume that the current water quality level that you indicated in Q #10 is to be changed to your acceptable water quality given in Q #12.

a. Would you be **willing to pay** $\underline{\$\ 4.00}$ each month for this change as long as you live in this area? (circle your answer) Yes No

b. What is the **maximum** that you would be willing to pay each month?
$______/month

15. Again, assume that the current water quality level you indicated in Q #10 is to be changed to your acceptable water quality level given in Q #12. What percentage change in certain pollutants would be required in your opinion to improve Bear Creek's surface water quality from the current level to what you think it should be? Please circle your answer for each item.

What percentage reduction should occur for . . .?

• Sediments (%) (e.g., Eroded soil)	0	20	40	60	80	100%
• Fertilizers (%) (e.g., Nitrate)	0	20	40	60	80	100%
• Herbicides (%) (e.g., Atrazine)	0	20	40	60	80	100%

16. Now let us assume that the current water quality level you indicated in Q #12 is to be changed to the **best quality level, that is, to level 10.**

a) Would you be **willing to pay** $\underline{\$4.00}$ each month for this change as long as you live in this area? (circle your answer) Yes No

b) What is the **maximum** that you would be willing to pay each month?
$_______/month

Please skip directly to Q #18.

17. You have indicated water quality level at 10 (the best) in Q #10. Assume that you want to continue the best water quality forever for the surface water in BC study area.

    a) Would you be **willing to pay** $4.00 each month as long as you live in this area to maintain the best water quality? (circle your answer) Yes No

    b) What is the **maximum** that you would be willing to pay each month?
    $_______/month

If you answered $0.00 to Q #14 or 16 or 17, please continue. If you did not, please go to Section 5.

18. What did you answer $0.00? Please indicate your reason

____ I do not make use of Bear Creek nor do I expect to use it.
____ I do not think it is appropriate to place a dollar value on water quality improvement in BC.
____ I am not comfortable placing a dollar value on water quality improvement in BC.
____ Other (Please specify) ____

SECTION 5: GROUNDWATER QUALITY OF THE BEAR CREEK WATERSHED.

People in Story and Hamilton Counties rely on groundwater as their primary source of drinking water. This water comes from shallow aquifers and deeper bedrock aquifers. The Iowa Groundwater Act of 1987 established as a goal for the state the prevention of groundwater contamination from point and non-point sources to the maximum extent possible.

19. In 1991, what were the sources of your drinking water for you and your family? (check all that apply)

____ Own groundwater well
(Please specify the approximate depth of the well ____ ft.)
____ Municipal water
____ Bottled water
(Specify approx. number of gallons consumed per month) ____
____ Other (specify) ____

20. Approximately what is your average monthly bill for water? ______________
If you obtain water from a municipal water source consider only the price that you pay each month for water and exclude the monthly sewage charge.

21 Please indicate what you think is the present groundwater quality beneath the Bear Creek watershed? (Use the same water quality ladder as before) Please circle your choice between 0 and 10.

0	1	2	3	4	5	6	7	8	9	10
Best										Unfit

If you indicated a water quality level of 10 (the best) in Q #21, go to Q #23. Otherwise, go to Q #22.

22. You have indicated a groundwater quality below the best (below level 10).

    a) Would you be **willing to pay** $10.00 each month for the improvement of water quality to the **drinkable level (level 10)** from any quality level below for as long as you live in the area? (circle your answer) Yes No

    b) What is the **maximum** that you would be willing to pay each month?
    $________/month

23. You have indicated water quality level at 10 (the best) in Q 321. Assume that you want to continue this best water quality forever.

    a) Would you be **willing to pay** $10.00 each month as long as you live in this area to maintain the best water quality? (circle your answer) Yes No

    b) What is the **maximum** that you would be willing to pay each month?
    $________/month

24. If you **answered $0.00 to Q # 22 or 23**, please **continue**. If you did not, please go to section 6.

_____ I do not make use of Bear Creek nor do I expect to use it.
_____ I do not think it is appropriate to place a dollar value on water quality improvement in BC.
_____ I am not comfortable placing a dollar value on water quality improvement in BC.
_____ Other (Please specify) ____

SECTION 6: SOIL CONSERVATION & STREAM ZONE PRACTICES

There are many soil conservation practices that farmers use to reduce erosion, protect the quality of their farmland and protect the waterways flowing through their fields. Grass waterways, terraces, planting on the contour and conservation tillage are examples of farming practices associated with maintaining quality farmland and protecting the environment.

Vegetative buffer strips, established along the banks of rivers, streams and waterways in agricultural lands, have gained attention as a possible land management practice designed to remove suspended and dissolved contaminants from over-land flow of water prior to entry into surface streams and groundwaters. Planted strips of permanent vegetation such as trees, shrubs and grasses are expected to slow down run-off water and intercept soil, water and contaminants within the vegetative strip. Also, the buffer strip is thought to be capable of absorbing some pollutants such as nitrates within the top few feet of soil.

25. Please circle your response for each statement.

SD = Strongly Disagree, SWD = Somewhat Disagree, N = Neutral, SWA = Somewhat Agree, SA = Strongly Agree, UN = Uncertain

	SD	SWD	B	SWA	SA	UN
• A vegetative buffer strip will reduce sediment entering a stream	1	2	3	4	5	6
• A vegetative buffer strip will reduce pesticide run-off into a stream	1	2	3	4	5	6
nitrate pollution in the root zone	1	2	3	4	5	6
• Planting crops up to the edge of a stream is acceptable	1	2	3	4	5	6
• A vegetative buffer strip will absorb						
• Conservation tillage on land up slope will reduce erosion and sedimentation	1	2	3	4	5	6
• Contour planting will reduce erosion and sedimentation	1	2	3	4	5	6
• Terracing practices will reduce erosion and sedimentation	1	2	3	4	5	6
• Using combinations of conservation tillage, contour planting, and terracing will be more effective in improving water quality than planting buffer strips	1	2	3	4	5	6

25. Please circle your response for each statement. (Continued)

SD = Strongly Disagree, SWD = Somewhat Disagree, N = Neutral, SWA = Somewhat Agree, SA = Strongly Agree, UN = Uncertain

	SD	SWD	B	SWA	SA	UN
• Using buffer strips in combination with one or more of the above measures will improve water quality the most	1	2	3	4	5	6

26. Assume for the moment that you own farmland in the Bear Creek watershed and that Bear Creek flows through it. Would you establish a vegetative buffer strip to help maintain or improve the Creek's water quality? (circle your answer)

Yes -----> Why? ____________________

No -----> Why not? ____________________

27. Please indicate what you consider to be an **acceptable cost sharing** scheme to finance the establishment and maintenance costs associated with vegetative buffer strips **voluntarily established** along Bear Creek.

Source of Cost Share	Cost Share Percentages
Farmer's share	____________
County share	____________
State Gov't share	____________
Federal Gov't share	____________
Other(s)____________	____________

28. How would you ensure the voluntary establishment of butter strips along Bear Creek?

____

29. a) Have you visited the buffer strip project site located on Mr. Ron Risdal's farm north of Roland to see first hand what it is about? (circle your answer)

Yes -----> How did you hear about the project?

No -----> ____________________

b) Have you seen a poster display or read an article published in the Story City Herald dealing with the risdal/Bear Creek buffer strip project?

Yes No

c) Have you attended any meeting where information concerning the Risdal/Bear Creek buffer strip project was presented?
Yes No

30. Would you like to visit the buffer strip on Mr. Risdal's farm during an organized extension field day?
Yes No

Q #31 should be answered only by part-time and full-time farmers. All others please go to Section 7.

31. Consider BC and the various drainages entering BC.

a) Would you be **willing to accept $125.00 each year per acre** or the voluntary establishment of a vegetative buffer strip along any waterway on your farmland? (circle your answer)
Yes No

b) What is the **minimum** that you would be willing to accept each year?
$________/month.

Comments: ____
____

SECTION 7: SOCIAL ACTION PLANS

By setting up a **"Creek Team Program" (CTP)**, people interested in the Bear Creek watershed would have a way to improve or maintain the quality of the water in the Creek. A program could be formulated that works at the "grass roots" level and provides many benefits for citizens living in the BC area. The program could be useful to educate others about Bear Creek, and to help determine acceptable ways to improve or maintain the water quality in Bear Creek and other waterways flowing through Iowa's agricultural landscape.

32. Please indicate the activity or activities that you might possibly be involved with as part of a CTP. Check all that apply.

_____ Monitoring water quality
_____ Planting stream-side trees, shrubs and grasses
_____ Taking inventory of resources of the Creek
_____ Rehabilitating older plantings
_____ Clean-up debris (plastics, bottles, and empty cans, etc.)
_____ Stocking fish/creating fish habitat
_____ Donate money
_____ Participate as a team leader and organize activities
_____ Other (Specify________________________________)

33. Now let us assume that you want to contribute your time to the CTP for BC.

a) Would you be **willing to spend** 5 days each year as long as you live in this area? (circle your answer) Yes No

b) What is the **maximum** that you would be willing to spend each year? ________days/year

SECTION 8: ABOUT YOU

34. How old were you on your last birthday?__________

35. Gender: Male_____ Female_____

36. Including yourself, how may people are living in your household? ________

37. How long have you lived at this location? ______________years.

39. What is the highest grade or level of regular school that you have completed including college, vocational or technical training?

1 = None
2 = 1-8
3 = 9-11
4 = 12 years, includes GED
5 = some college, vocational or technical training
6 = Bachelors degree
7 = Masters degree
8 = Professional (PHD, MD, DVM, etc.)

40. Please circle the category that comes closest to your household's gross income from all sources (wages, investments, and part-time jobs) in 1991? Would you say it was? (circle your answer)

1 = under $10,000
2 = $10,000 - $19,999
3 = $20,000 - $29,999
4 = $30,000 - $39,999
5 = $40,000 - $49,999
6 = $50,000 - $75,000
7 = greater than $75,000

41. **We have now concluded the questionnaire.** Do you have any questions or would you like to comment about this survey or anything related to the Bear Creek watershed?

____

____

____

Thank you very much for your time. The Leopold Center for Sustainable Agriculture and researchers in the Department of Agronomy, Economics, Geology and Forestry at Iowa State University appreciate your input and cooperation.